EXAMINING THE NATURE OF INSTRUCTIONAL PRACTICES OF SECONDARY MATHEMATICS PRE-SERVICE TEACHERS

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Submitted to the Graduate Faculty of

School of Education in partial fulfillment

of the requirements for the degree of

Doctor of Education

University of Pittsburgh

2006

UNIVERSITY OF PITTSBURGH

SCHOOL OF EDUCATION

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October 23, 2006

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The purpose of this study was to describe the instructional practices of two pre-service secondary mathematics teachers, Paige Morris and Keith Nichols, during their internship experiences. Specifically, the study aimed to examine the cognitive demands of the tasks as selected and enacted by the pre-service teachers, the mathematical representations used during the lesson, and the questions asked by each pre-service teacher. Additionally, the study aimed to describe the ways in which the contextual settings, particularly the curriculum and mentor, appeared to influence the instructional practices of the pre-service teachers as they planned for and enacted mathematics lessons in their field placements.

The analysis of the data indicated that the instructional practices of the pre-service teachers were quite different. Keith planned for and enacted more high-level tasks than did Paige. While both Paige and Keith provided their respective students with opportunities to consider multiple representations of a mathematical idea, the use of the representations differed. Paige focused on procedural aspects of making connections between representations, whereas Keith used the representations as a way for the students to build meaning of the mathematical concepts. Additionally, Keith asked more questions that provided the students with opportunities to think

and reason about the mathematics as well as to make meaningful connections between representations.

An analysis of the contextual settings in which Paige and Keith worked point to key differences in the opportunities that Paige and Keith had during their field experience to learn about student-centered instructional practices. Two specific areas that were targeted in this study were the curriculum and the mentor. A review of the data indicated that the curriculum used in field experience and the mentoring that Paige and Keith received from their mentor teachers and university supervisors appeared to affect aspects of their practice. That is, Keith was greatly influenced by his use of a reform-oriented curriculum, whereas Paige did not have access to such a curriculum. Additionally, Keith’s mentors consistently used specific instances form the lesson as a means to identify key areas for Keith to focus on improving. In contrast, Paige typically received feedback that was broad and general.

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PREFACE

I am indebted to so many people for their help, support and encouragement throughout my work on my dissertation. First I would like to thank Margaret (Peg) S. Smith for being my own educative mentor throughout my graduate studies, and in particular, throughout my work on my dissertation. Her timely and specific feedback always challenged me to think more deeply than I ever thought possible. I am also grateful for the opportunities I had to work with her in a variety of teaching and professional development settings. I have learned so much from her. I am a better student, teacher, and professional because of her influence.

I am thankful for Ellen Ansell, Ellice Forman, and Mary Kay Stein's willingness to be on my committee. The feedback and support they provided strengthened my study greatly. I consider it a privilege to have worked with them.

I am grateful for the support from my fellow graduate students- Melissa Boston, Amy Hillen, Elizabeth Hughes, and Michael Steele. I enjoyed (and will miss) all the e-mails, lunches, DFG's, and chats in the office. I am also appreciative to my colleagues at the Knowles Science Teaching Foundation. They always new when to let me walk around, and when to kick me back into my office.

I especially want to thank my family for their love and support. My mother has always encouraged me to “go for it”- thank you. Hey dad, now there’s actually a DR in the family! The Rizor family was also a great source of support and encouragement.

Finally, I am eternally grateful to my partner, Erin Rizor. Her constant love, support, and encouragement were amazing. I never would have made it through without her. I also am blessed for the love and smiles our son, Laz, provided. His timing was always perfect!

1.0 CHAPTER ONE

1.1 INTRODUCTION

Over the past two decades mathematics assessments at both international and national levels have indicated that United States students' performance is inadequate. Results from assessments such as the Trends in International Mathematics and Science Study (TIMSS) and the National Assessment of Educational Progress (NAEP) point to the fact that students in this country are not performing well in mathematics. In 1999, the United States average mathematics score for the eight grade on TIMSS ranked 19th out of 38 participating countries. In 2003, the United States average math score ranked 15th out of 27 participating countries (NCES, 2000, 2003). At the national level, results from the seventh NAEP, which was administered in 1996, indicate that 38% of 8th graders and 31% of 12th graders performed below the basic level of mathematical achievement (Dossey, 2000). While students do struggle somewhat with basic computation problems (Dossey, 2000), performance is notably low on extended-constructed response (ECR) tasks. These tasks involve solving a problem and providing justification for the given solution, thus providing insight into students' thinking and reasoning. Silver, Alacaci, and Stylianou (2000) found that "students generally omitted or performed poorly on most extended-constructed response tasks….with as little as 2 percent, and no more than about 30 percent, of the students responding satisfactorily across twenty-three tasks at three grade levels" (p.303). The eighth NAEP was administered in 2000. Results indicate that there was improvement at the 8th grade level, but not at the 12th grade level. The average mathematical scale score (e.g. 0-500) for 8th

grade increased from 272 in 1996 to 275 in 1998. Only 34% of 8th graders performed below the basic level of mathematical achievement, a decrease of 4% from the previous NAEP. At the 12th grade level, however, the average scale score declined from 304 to 301, and the percent of students performing below the basic level of mathematical achievement increased by 4%; that is, 35% of the 12th graders did not demonstrate a basic or proficient knowledge of mathematics (Braswell et al, 2001).

One explanation for U.S. students' poor performance on these assessments, especially on the ECR tasks that require a deeper understanding of mathematical concepts, might be the opportunities students have to learn mathematics. Several studies (e.g. Grouws & Smith, 2000; Hiebert and Wearne, 1993; McCaffrey et al, 2001; Stigler & Hiebert, 1999; Stein & Lane, 1999) have examined the link between instructional practices of mathematics teachers and student learning. The findings indicate that differences in instructional practices lead to differentiated student learning. Specifically, student learning gains are highest when students are engaged in tasks and classroom practices that provide opportunities to think and reason about mathematics. That is, the instructional practice of teachers is one possible indicator of student performance.

It is important then that teacher education programs provide pre-service teachers with opportunities both in the university setting and in the field experience classroom to develop instructional practices that support students' development of mathematical understanding. This study examines the instructional practices of two pre-service secondary mathematics teachers who are enrolled in a teacher education program that focuses on providing pre-service teachers with opportunities to develop instructional practices that support students as they engage with challenging mathematical tasks. In addition, this study seeks to identify aspects of the pre-service teacher's field placement that appear to influence the instructional practices.

The following sections examine the opportunities students are provided to learn mathematics, particularly with respect to the instructional practices in mathematics classrooms. Next, recommendations for tasks, tools, and normative practices that promote understanding are explored. Then, curricula that support the recommended instructional practices are described. Finally, the opportunities for pre-service teachers to learn about new instructional practices are discussed.

1.2 STUDENTS' OPPORTUNITIES TO LEARN

Students learn what they have the opportunity to learn (Stigler & Hiebert, 1999; Hiebert, 2003). Stigler and Hiebert (1999) state, "both the level and nature of the content to which students are exposed set boundaries on students' learning opportunities" (p.56). When the focus of instruction is memorizing and using procedures, students develop a procedural understanding of mathematics; however, if, for example, students are given the opportunity to explore the concepts underlying a procedure, then the learning will be more conceptual in nature. Students with a solid conceptual understanding of mathematics are better able to solve novel problems (Skemp, 1976), which is a critical skill needed by students in today's society (Hiebert et al, 1997; NCTM, 2000). Conceptual understanding involves connecting pieces of knowledge in a meaningful way (Skemp, 1976; Hiebert et al, 1997) so that one can move flexibly between and among various mathematical representations (Dreyfus & Einsberg, 1996; NRC, 2001; Lesh, Post, Behr, 1987; NCTM, 2000; Pape & Tchoshanov, 2001), communicate mathematical ideas (Hiebert et al, 1997; Carpenter & Lehrer, 1999; NCTM, 2000) and make connections between various mathematical ideas (NRC, 2001). Therefore, if students are expected to develop a conceptual understanding of mathematics, they need opportunities to do this in their mathematics classrooms. However, large-scale international and national studies show U.S. teachers are rarely providing students with opportunities to develop conceptual understanding.

The TIMSS video study (Stigler & Hiebert, 1999) paints a less than desirable portrait of mathematics classrooms in the United States. The study found that U.S. students were not engaging in the same level of mathematics as countries such as Germany and Japan. The overall focus of mathematics lessons in the U.S. was on memorizing and performing procedures instead of developing concepts. Almost 90% of the U.S. lessons observed were coded as having low quality of mathematical content, compared to only 11% in Japan and 34% in Germany. Further analysis revealed a lack of mathematical coherence throughout US lessons; that is, lessons often addressed various unrelated mathematical topics and failed to build on prior knowledge in a meaningful way. The tasks used in the classroom as well as the enactment of those tasks focused students on practicing procedures and skills. This is also supported by data from the 1999 TIMSS questionnaire. Nearly all of the U.S. students (94%) reported that their teachers consistently model how to solve mathematics problems (NCES, 2000). Overall, the U.S. students were not being asked to think and reason about mathematics in a meaningful way.

Data from the NAEP also substantiate the fact that a majority of U.S. students are not provided with opportunities to engage in activities that promote conceptual understanding. Grouws and Smith (2000) summarized findings from the teacher questionnaire portion of the 1996 NAEP. They indicated that 79% of eighth-grade students have teachers who report focusing instructional practices on procedural aspects of mathematics “a lot”, while only approximately 50% of the students have teachers who report focusing on more conceptual aspects such as reasoning and communication “a lot”. Those students whose teachers reported providing more opportunities to engage with the conceptual aspects of mathematics had significantly higher average scale scores than those students whose teachers reported little or no focus on conceptual aspects; in addition, the more focus teachers reported on developing procedural aspects of mathematics, the lower the students' average scale scores. Data from the eight NAEP indicate that students in 8^{th} and 12^{th} grade who viewed mathematics as useful tool for solving problems scored highest, while the students who viewed mathematics as memorizing facts believed that there was only one method to solve mathematical problems scored the lowest (Braswell et al, 2001).

Together, data from both the TIMSS and the NAEP provide insight into why students in the United States tend to have a largely procedural knowledge of mathematics. While procedural knowledge is a critical part of mathematical understanding, it is only one strand of knowledge needed to be proficient in mathematics (NRC, 2001). Students in the U.S. can, and must, learn more mathematics (Hiebert, 2003). In our rapidly changing technological society, the level of mathematical understanding needed for day-to-day life as well as in the workplace is at an all time high. Mathematical understanding is critical for success in a changing world. Students need to apply knowledge and understanding to novel situations, communicate mathematically, and use a variety of tools (i.e., graphing calculators and computers) to solve complex mathematical problems (NCTM, 1989, 2000; Hiebert et al, 1997), all of which involve a conceptual understanding of mathematics. Therefore, teachers must provide students with opportunities to develop a conceptual understanding of mathematics.

1.3 NEW OPPORTUNITIES FOR STUDENT LEARNING

We are in the midst of a reform in mathematics teaching and learning. The impetus behind the current reform has strong roots in the assessments described earlier that portray dismal student progress in mathematics as well as a lack of opportunity for students to move beyond procedural knowledge. A leading force in the current reform is the National Council of Teachers of Mathematics (herein referred to as NCTM). A key goal of the reform outlined by *The Curriculum and Evaluations Standards for School Mathematics* (referred to as Standards) and the *Principles and Standards for School Mathematics* (referred to as PSSM) is to influence both what mathematics students learn and how they learn it (NCTM, 1989, 1991, 2000). Both the documents advocate a shift away from the traditional format of a teacher-directed classroom that focuses on learning procedures and towards a student-centered classroom that focuses on developing a deeper, conceptual understanding of the mathematics.

In order to accomplish this goal, the instructional practices of teachers must change. Carpenter and Lehrer (1999) identify three "critical dimensions" of instructional practice that are essential to examine when considering the opportunities students are provided to learn mathematics: 1) tasks, 2) tools, and 3) normative practices. The following sections define each dimension and describe the types of instructional practices that have potential to provide students with the opportunity to develop a conceptual understanding of mathematics.

1.3.1 Tasks

Stein and Lane (1996) define a task as "an activity engaged in by teachers and students during classroom instruction that is oriented toward the development of a particular skill, concept, or idea" (p.54). A task could be one complex problem or a series of related problems. Tasks form the basis for students' opportunities to learn mathematics since the types of tasks students work on focus their thinking towards particular mathematical ideas (Hiebert et al., 1997). However, "not all tasks are created equal, and different tasks will provoke different levels and kinds of student thinking" (Stein et al., 2000, p. 3). Research suggests that the tasks in which students engage during a mathematics class and the methods used to implement the tasks are critical factors in the students' learning of mathematical concepts, as well as in their learning of what it means to "do" mathematics (Doyle, 1983; Hiebert et al., 1997; Lappan & Briars, 1995; Stein & Lane, 1996; Stein, Grover, & Henningsen, 1996).

When selecting tasks for instruction, then, teachers need to consider the mathematical "residue" (Hiebert et al., 1997, p.22) a task will leave with the students. That is, teachers need to determine the potential the task has for allowing students to engage in thinking, reasoning, communicating, and making connections between mathematical concepts and representations, as these are fundamental characteristics of conceptual understanding. Tasks that provide these opportunities are referred to as high-level tasks because the tasks place a great deal of cognitive demand on the students. Conversely, tasks that focus students' attention on memorization and using procedures without understanding are referred to as low-level tasks (Henningsen & Stein, 1997; Stein & Lane, 1996; Stein, Grover, & Henningsen, 1996).

High-level tasks provide students with opportunities to develop and deepen conceptual knowledge in a variety of ways. High-level tasks often have multiple solution paths, which allows for communication, reflection, and analysis of various methods (Carpenter & Lehrer, 1999). High-level tasks often use multiple representations and require students to make connections between and among various representations. The focus of the task is on understanding an underlying mathematical idea rather than on purely memorizing a procedure. The mathematics of a high-level task is problematic for the students. The challenge of the task for the students lies in grappling with and coming to a better understanding of the mathematics, rather than deciphering the context of the problem or convoluted directions. High-level tasks allow students to use and build on their prior knowledge in a meaningful way, reflect on their learning, and communicate with others about the mathematics (Carpenter & Lehrer, 1999; Hiebert et al, 1997; Henningsen & Stein, 1997; Stein & Lane, 1996; Stein, Grove, & Henningsen, 1996).

One high-level task alone, however, does not solidify conceptual understanding. Rather, the greatest potential to elicit and solidify conceptual understanding involves the careful sequencing of lessons that center on cognitively demanding tasks. The mathematical coherence of lessons is a critical factor in providing students the opportunity to develop a solid understanding of the mathematics (NCTM, 2000; Stigler & Hiebert, 1999), since

> student understanding is built up gradually, over time, and through a variety of experiences. This means that the selection of appropriate tasks includes thinking about how tasks are related, how they can be chained together to increase opportunities for students to gradually construct their understanding (Hiebert et al. 1997, p.31).

1.3.2 Tools

As students work on tasks, they should have the opportunity to draw on various tools to aid in their engagement with the mathematics (Carpenter & Lehrer, 1999; Hiebert et al, 1997). Tools include physical materials such as paper and pencil, technological aides (i.e., calculator), and different representations. Lesh, Post, and Behr (1987) identified 5 types of representations in mathematical learning: 1) real-world contexts, 2) manipulative models, 3) pictures/diagrams, 4) spoken language, and 5) written symbols. Each representation is independently important since each focuses a student’s attention on separate characteristics of the underlying structure of the concept (Lesh, Landau, & Hamilton, 1983; NCTM 2000). However, understanding each representation independently is not enough to develop a conceptual understanding. Translating between the representations as well as transforming within the representations is critical in developing a flexible and fluid understanding of a mathematical concept (Lesh, Landau, & Hamilton, 1983; Lesh, Post, & Behr, 1987; Pape & Tchoshanov, 2001). Using different tools provides students with a variety of ways to think about and explore a mathematical concept, thus providing students opportunities to create an integrated web of understanding around that concept.

Hiebert et al (1997) describe tools as “learning supports” (p.20) that can be used to facilitate learning in three specific ways. First, tools allow students to create a record of their thinking and reasoning. This may involve a written notation (either using standard notation or student designed) or the use of manipulatives. These tools may then be used for a second purpose, as an effective means of communication. Communication is critical in developing understanding. As students discuss and reflect on their thinking process as well as the thinking of others, they have the opportunity to develop a deeper understanding of how different representations model the same situation, and tools greatly facilitate these conversations. Finally, tools provide students with a means to think through difficult tasks. Tools support student thinking by connecting to prior knowledge, extending “mental capabilities”, and influencing the way one views or thinks about a particular task.

Tools may be introduced by either the teacher or the student. There is no “right” tool to use in every situation. Instead, it is critical that the teacher “thinks carefully about the way in which students' thinking might be shaped by using particular tools" (Hiebert et al, 1997, p.63), since this will impact the residue that is left behind from engaging with the task.

1.3.3 Normative Practices (Norms)

Stigler and Hiebert (1999) warn, "challenging content alone does not lead to high achievement. The same content can be taught deeply or superficially" (p.58). The teacher plays a critical role in how tasks will materialize in the classroom. The events of the classroom provide students with opportunities to engage with and learn mathematics (Hiebert et al, 1997; Stein & Lane, 1996; NCTM, 2000). While the selection of a cognitively demanding task is important, the way in which the students actually experience the task is what essentially impacts student learning (Ball & Cohen, 1996; Stein & Lane, 1996). Conceptual understanding is not something that is directly taught. As the types of tasks change from the procedural, or low-level tasks, to tasks that require a high-level of cognitive demand, the teaching methods needed to support student learning must also change (Hiebert et al, 1997). As a result, the normative practices, or norms, in the classroom will also change. The norms in a classroom involve the role of the teacher and students; that is, "how students and the teacher are expected to act or respond in a particular situation" (Carpenter & Lehrer, 1999, p.25). The norms of a classroom dictate how tasks and tools will be made use of during the class. Norms can be either explicitly stated or learned implicitly through interactions (Carpenter & Lehrer, 1999). Identifying the norms of a classroom is important, as the norms determine the way a task will be enacted, and ultimately, the way students will come to learn about and view mathematics.

Hiebert et al (1997) identify four norms that promote conceptual understanding in classroom:

1) discussions are about methods and ideas,
2) students choose their own methods and share them with others,
3) mistakes are sites for learning, and
4) correctness is determined by the logic of the mathematics (p.46-49).

As previously stated, discussing the relationship between and among various representations is critical in developing a conceptual understanding of a particular mathematical idea. When students decide how to approach a problem, they are able to draw on their prior knowledge in a meaningful way. In sharing solutions with others, students are given the opportunity to reflect on and evaluate the effectiveness and correctness of their own work as well as the methods and tools used by other students. While the students are engaging with and communicating about the task, mistakes should be seen as a "natural and important part of the process of improving methods of a solution" (Hiebert et al, 1997, p.48). Rather than being seen as a sign of lack of knowledge, mistakes should be seen as a way to build a better understanding. Students should come to learn that they, not the teacher, are the mathematical authority in the classroom. One way of achieving this shift in authority is to use the logic of mathematics to ultimately determine the correctness of a method and solution.

Traditionally, the role of the teacher in a mathematics classroom is that of a "didactic leader" (Leinhardt, 1993, p.4). The teacher is seen as the mathematical authority, the one who determines the correctness of a method and solution. The teacher directs the classroom by instructing students on how to correctly perform a procedure, and then students work individually to practice the procedure on similar problems (Lloyd, 1999; Senk & Thompson, 2003b). Little, if any, emphasis is placed on developing a deep understanding of the rationale behind or connections among various procedures (Stigler & Hiebert, 1997; Stigler & Hiebert, 1999; Hiebert, 2003). Students are rarely provided with the opportunity to reflect on or communicate their thinking. This method of teaching typically does not address "the way in which either the teacher or the student might develop the meaning and the structure of the material being learned" (Leinhardt, 1993, p.5). While this type of teacher-centered instruction dominated mathematics classrooms in the U.S. for nearly all of the 20th century (Hiebert, 2003), it is contrary to current thinking on how students best learn and understand mathematics.

In a reform-oriented classroom, the class structure is very student-centered and the teacher is viewed as a "facilitator" (Leinhardt, 1993, p.3). The teacher role shifts from the "teller" in the traditional classroom to the "questioner" in the reform-oriented classroom. Questioning is a critical component in creating norms that support the development of conceptual understanding among students since questions provide the teacher with a vehicle to assess and advance understanding, promote communication, and focus on the logic of the mathematics.

Effective lessons are built around students' prior knowledge rather than a particular page in a textbook (Van de Walle, 2004). The typical reform-oriented class format involves the teacher posing a high-level task and allowing students to work in groups to solve the task using a method that makes sense to that particular group of students (Senk & Thompson, 2003b). As the students work on the task, the teacher moves around the classroom asking questions about students' thinking and reasoning. After students have explored the task, the class typically reconvenes as a group to discuss various methods and solutions. During the discussion, students explore misconceptions, the efficiency of various methods, and ultimately they determine the correctness of solutions by using mathematical reasoning. The teacher is the facilitator of the discussions between groups and the class, rather than a lecturer who passes on knowledge to quiet, passive students. Through careful planning, sequencing of tasks, and questioning, the teacher guides students along a particular mathematical trajectory by providing opportunities to engage in high-level tasks, communicate with other students, reflect on various methods, and to use tools in a meaningful way.

1.4 USING REFORM-ORIENTED CURRICULUM AS MEANS TO PROVIDE STUDENTS WITH OPPORTUNITIES TO DEVELOP CONCEPTUAL UNDERSTANDING

In order for students to develop more than a procedural understanding of mathematics, the instructional practices of mathematics classroom must change from the traditional format of a skills-based teacher-centered classroom to that of conceptually-oriented student-centered classroom. As discussed in the previous section, this shift involves using cognitively demanding tasks, an assortment of tools in a meaningful way, and redefining the norms of a mathematics classroom. Research suggests, however, that implementing these new instructional practices is often a struggle for teachers (Cohen, 1990; Manouchehri & Goodman, 2000; Orrill & Anthony, 2003; Wilson & Lloyd, 2000).

There are various factors documented in the literature (e.g., Brown & Borko, 1992; Fennema & Franke, 1992; Henningsen & Stein, 1997; Thompson, 1992) that influence a teacher’s instructional practices. One critical factor that influences the instructional practices used by the teacher is the textbook. Students’ opportunities to learn mathematics are directly related to the tasks in which they engage, and teachers are the critical determinants of those tasks. The primary resource teachers use to select tasks is the textbook being used in the classroom (Senk & Thompson, 2003b; Van Zoest & Bohl, 2002). Research indicates that teachers rely quite heavily on textbooks for planning and teaching mathematics (Brown & Edelson, 2004; Ball & Cohen, 1996; Remillard, 2004). Van Zoest & Bohl (2002) claim, “textbooks can strongly influence both what and how teachers teach” (p.268). That is, the textbook is a key factor in determining the instructional practices of a mathematics classroom.

Since the advent of the *Standards* (NCTM, 1989), there has been an effort to develop curriculum materials (i.e., textbooks, computer software, and teacher resource books) that are more closely aligned with the goals of the *Standards* (McCaffrey et al, 2001; Senk & Thompson, 2003b). One notable effort occurred two years after the release of the *Standards* when the National Science Foundation (NSF) stated that it would fund the development of such materials. The NSF initially funded 12 large-scale projects that together spanned from kindergarten through 12th grade (McCaffrey et al, 2001; Senk & Thompson, 2003b) and has subsequently funded revisions of three curricula, one each at the elementary, middle, and high school levels. In addition to the NSF funded curricula, several other reform-oriented curricula (ROC) have been published that embody the ideals of the *Standards*.

ROC are different from traditional curricula with respect to tasks, tools, and norms (Lloyd, 1999; Lloyd & Frykholm, 2000, NCTM, 1989; NCTM, 2000; Senk & Thompson, 2003b). ROC are designed to support the use of the instructional practices identified as critical to the development of a conceptual understanding of mathematics. As a result, ROC provide students with different opportunities to learn mathematics than do traditional textbooks.

Tasks in a traditional mathematics textbook focus students’ attention on skills and becoming efficient with various procedures. These traditional textbooks have “few references to mathematical principles, very little to read, and thousands of exercises to practice skills. There

[are] virtually no problems showing how mathematics is used in daily life or in other fields and no challenging problems in these texts" (Senk & Thompson, 2003b, p.9). Overall, the majority of tasks in traditional textbooks would be classified as low-level. In addition, the teaching suggestions in traditional textbooks typically focus on the teacher showing students how to use a particular procedure for the problems in the lesson. Thus, as a whole, traditional textbooks provide little opportunities for students to engage with tasks that promote conceptual understanding.

In contrast, the tasks in ROC are largely high-level tasks and the suggested instruction in the teacher's manual focuses on providing students with opportunities to grapple with the cognitively challenging aspects of the tasks. That is, the tasks often involve real-world situations, allow for multiple solution paths, require students to make connections between and among various representations, and focus students' attention on understanding the underlying mathematical ideas of the task rather than on purely memorizing a procedure. While procedures are not absent in ROC, the method used to learn the procedures is different from the traditional curriculum. Often, the problems are structured to begin with students' informal knowledge of the concept. Then through methods such as discussing various solution methods, the teacher helps guide the students' learning of the concept.

Given the tradition of mathematics instruction in the U.S., it is not surprising that ROC "challenge strongly held beliefs about what mathematics is most important as well as how it is taught and learned most effectively" (Senk & Thompson, 2003b, p.15). With that in mind, Brown and Edelson (2003) emphasize the importance of examining how teachers select and implement tasks from ROC. They note that the use of a ROC alone does not imply that teachers are using the curriculum in the way it was intended. That is, teachers may appropriate tasks and use them as they appear in the curriculum (Remillard, 1999), modify tasks in some way (Smith, 1999), or invent new tasks to replace the tasks from the curriculum (Remillard, 1999). The modified or invented tasks may be similar to or different from the original task. One risk with curricular reforms is that while using the curriculum materials, “practitioners will ‘mutate’ the core aims of the reform to take on the characteristics the reforms seek to change” (Remillard, 1999, p.1). Sometimes, this mutation is done knowingly, while other times, the teacher does not recognize the mutation of the goals. Therefore, new curriculum materials are not a panacea, but rather a starting point. They provide a source for good tasks, but in order to enact tasks as intended, new instructional practices will be required.

One key place where teachers have an opportunity to learn about new instructional practices is in pre-service teacher education programs. Teacher education programs play a critical role in the reform efforts in that the programs are preparing the next generation of teachers, and these teachers will be expected to help their future students develop a conceptual understanding of mathematics. In the next section, ways in which pre-service teachers begin to learn about new instructional practices will be explored.

1.5 PREPARING TEACHERS TO MEET THE DEMANDS OF TEACHING FOR UNDERSTANDING

As teachers enter the profession, they may already have well-defined beliefs regarding the instructional practices of a mathematics classroom. This is what Lortie (1975) calls the “apprenticeship of observation”; that is, the teachers learn what teaching mathematics looks like through their own schooling experiences. As previously noted, the last century was dominated by teacher-centered classrooms in which procedural tasks were the main focus of classroom activity. As a result, most teachers have a traditional view of mathematics instruction. This creates the need to provide teachers, both new and veteran, with opportunities to learn about and engage in the primary tenants of the reform outlined by documents such as the *Standards* and *PSSM*. This is challenging because teachers will need to redefine “good” instructional practices in a mathematics classroom (Ball, 1988). There are two primary places where teachers may have an opportunity to learn about instructional practices that are student-centered: during pre-service teacher education experiences (ie., coursework and field placements) and through on-going professional development opportunities.

Shortly after the introduction of the *Standards*, many researchers began to call for mathematics pre-service teacher education programs to restructure the coursework and field experience components to align with the instructional practices recommended by the reform. For example, Wilson (1994) encourages teacher educators to provide pre-service teachers with an opportunity to engage in cognitively demanding tasks and to reflect on their learning. The premise is that “such an approach will allow [pre-service] teachers to make important connections in their own mathematical understanding and improve the chances that such an integrated approach will be reflected in their future teaching” (p.369). One resource teacher educators can use to achieve this goal is ROC. In addition to coursework, other researchers focus on the importance of the field experience component. For example, Eisenhart et al (1994) and Frykholm (1996) claim that the pre-service teacher’s field experience greatly impacts the pre-service teacher’s future instructional practices. As a result field experiences should model the student-centered instructional practices that pre-service teachers are expected to learn. The following sections further elaborate on the influence of ROC and the field experience in pre-service teacher education.

1.5.1 ROC and Pre-Service Teacher Education

A growing trend in pre-service teacher education is to use tasks and lessons from ROC in methods classes as a means to engage pre-service teachers in thinking about teaching (Behm & Lloyd, 2003; Lloyd & Frykholm, 2000; Smith et al, 2001; Smith et al 2003; Spielman & Lloyd, 2004). ROC may serve as a resource for teacher learning as well as student learning. Through engaging with ROC in a variety of ways, teachers have opportunities to begin to overcome the "apprenticeship of observation" by participating in and reflecting on new instructional practices. For example, Smith and her colleagues (Smith et al, 2001; 2003) used high-level tasks from a variety of ROC in order to provide pre-service teachers with the opportunity to do mathematics and think critically about the planning of lessons surrounding high-level tasks. The pre-service teachers also engaged in analyzing teaching episodes from lessons based on tasks from ROC. Several researchers (e.g., Behm & Lloyd, 2003; Lloyd & Frykholm, 2000; Spielman & Lloyd, 2004) have a different approach-- to use ROC as the textbook for a methods course. This provides pre-service teachers with the opportunity to experience a particular ROC, examining both the mathematical content as well as the pedagogical methods suggested in the text.

Research indicates that the use of ROC positively impacts pre-service teachers' knowledge of mathematics and beliefs about the teaching and learning of mathematics (Behm & Lloyd, 2003; Lloyd & Frykholm, 2000; Spielman & Lloyd, 2004). These findings are notable since other research indicates that beliefs and content knowledge are factors that influence both what and how a teacher teaches (Clarke,1997; Thompson, 1992; Fennema & Franke, 1992; Remillard, 1999; Senk & Thompson, 2003b; Van Zoest & Bohl, 2002).

The vast majority of the work described above, however, has been done at the elementary and middle school levels; little research examines pre-service teachers at the high school level. In addition, little research explores how the knowledge gained in methods courses influence instruction in the student teaching setting. That is, further research is needed to examine the extent to which pre-service teachers plan and teach lessons that reflect instructional practices aligned with the reform, such as the implementation of high-level tasks as a means to develop conceptual knowledge among students (Lloyd & Frykholm, 2000; Orrill & Anthony, 2003). This is critical since the teacher ultimately shapes the learning opportunities and experiences of the students (Ball & Cohen, 1996; Hiebert et al, 1997; Lloyd & Frykholm, 2000; NCTM, 2000; Stein & Lane, 1996).

1.5.2 The Field Experience: The Role of the Mentor

The experiences in pre-service teachers' coursework are critical to developing knowledge and beliefs that encourage the use of reform-oriented instructional practices; however, the coursework alone is "ultimately a weak intervention" in that pre-service teachers often revert to traditional teaching methods during their field experiences (Ebby, 2000, p.70). One possible reason that pre-service teachers may teach in a way that contradicts the methods they are learning in the methods courses is that while in the field placements the pre-service teachers "feel almost no pressure" from their mentor teachers to use instructional practices aligned with the reform (Frykholm, 1996, p.671). Frykholm also observed that over half of the pre-service teachers in his study claimed that their mentor teacher most impacted their own teaching philosophies. In addition, almost two-thirds of the pre-service teachers stated that their teaching style mimicked their mentor's style to a high degree. It is not surprising, then, that in the lessons Frykholm observed, approximately two-thirds were categorized as "traditional" lessons.

Data from such studies point to the profound influence a mentor teacher may have on the instructional practices of the pre-service teacher. An important aspect for teacher education programs to consider, then, is the alignment between their program and the field placement, particularly the beliefs and practices of the mentor teacher. Eisenhart et al (1994) claim that the most important aspect of a pre-service teacher education program is that the field placements for the pre-service teachers be in classrooms that "provide the opportunity and support to teach in ways that match the NCTM's vision" (p.37).

There is evidence that creating this alignment between the program and field placement is effective. For example, a study by Van Zoest & Bohl (2002) of an intern and mentor teacher demonstrates a clear impact of the mentor teacher on a pre-service teacher's instructional practices. Through their joint planning sessions, the pre-service teacher grappled with both mathematical and pedagogical decisions regarding how to use the materials in the ROC in a way to best serve the students' learning. The willingness, commitment, and support of the mentor impacted the pre-service teacher's use of and interaction with the ROC materials. Ebby's (2000) work also highlights the positive impact on pre-service teachers' instructional practices when there is an alignment between coursework and the field experience. While there is a growing body of research that continues to examine the impact of the mentor-pre-service teacher relationship on the pre-service teacher's instructional practices, the research that focuses on the impact of the alignment of a pre-service program and field placement, including the curricula used in the classroom and the instructional practices of the mentor teacher, is still in its infancy.

1.6 PURPOSE OF THIS STUDY

This study used a case study design to investigate the instructional practices used by two secondary mathematics pre-service teachers who participated in a reform-oriented teacher education program and the ways in which aspects of the context within which they work, particularly the mentor teacher and the curriculum used in the classroom, appear to influence the practices used by each of the two pre-service teachers. Specifically, this study seeks to address the following questions:

1) What is the nature of instructional practices used by two pre-service secondary teachers in their field placement classrooms?
2) In what ways do the contexts within which each pre-service teacher works influence their instructional practices?

The purpose of the first research question is to describe the selection and enactment of tasks by pre-service teachers in their field placement. In particular, the nature of the tasks, the tools, and normative practices will be explored. The second research question aims to examine the impact of aspects of the contextual setting on instructional practices. In particular the question seeks to compare the instructional practices of a pre-service teacher who uses traditional curricula with one who is exposed to a reform-oriented curricula. Additionally, the second questions seeks to explore the influence of mentors who regularly use high-level tasks, provide students with appropriate and meaningful tools, and whose classroom norms promote conceptual understanding on the instructional practices of the pre-service teachers.

1.7 SIGNIFICANCE OF THE STUDY

The current study builds on prior studies that have informed the field about the critical dimensions of instructional practices. Specifically, this study is informed by prior research that examined the tasks used in elementary classrooms (Hiebert & Wearne, 1993) and middle school classrooms (Stein & Lane, 1996; Stein et al, 1996; Henningsen & Stein, 1997), the use of representations as a tool to promote understanding (Even 1993, 1998; Knuth, 2000; Sanchez & Llinares, 2003; Wilson 1994), and the use of questioning as a normative practice (Hiebert & Wearne, 1993; Boaler & Brodie, 2004; Martino & Maher, 1999; Moyer & Milewicz, 2002).

While each of the studies provides insight into a particular aspect of the critical dimensions of instructional practices, the studies do not address how all three aspects are combined during instruction, particularly at the secondary level with pre-service teachers. The studies on representations as tools focus on pre-service teacher's content knowledge, but do not address how this knowledge translates into instruction in the classroom. Three of the studies about questioning involve classroom practices of practicing teachers (i.e., Hiebert & Wearne, 1993; Boaler & Brodies, 2004; Martino and Maher). While Moyer and Milewicz (2002) do focus on pre-service teachers, the study examines elementary teachers as they interview students in a non-instructional setting. This study will expand this research base by characterizing the instructional practices of two secondary pre-service teachers who are participating in a program that promotes student-centered instructional practices as a means of developing conceptual understanding among students.

Improving student learning is a central goal of mathematics education. As discussed previously, to achieve this goal the instructional practices of teachers must improve. Several studies (e.g., Clarke, 1997; Henningsen & Stein, 1997; Lloyd, 1999; Remillard, 1999; Van Zoest & Bohl, 2002) have identified factors that influence teacher's use of high-level tasks. However, research is sparse regarding the influences on the use of tools and normative practices. In addition, little research examines the influences on pre-service teacher's instructional practices, particularly at the secondary level. We need to understand how the context of the pre-service teachers' experiences influence their instructional practices so that teacher education programs can be designed to produce teachers who have developed instructional practices that promote understanding. Therefore, this study will document ways that various aspects of the context, particularly the mentor and curriculum, appear to influence the instructional practices of secondary pre-service teachers. This study then has implications for pre-service teacher education programs in that it will explore how aspects of the context appear to support or inhibit pre-service teachers' implementation of student-centered instructional practices.

1.8 LIMITATIONS OF THE STUDY

While this study aims to inform the mathematics education field about the instructional practices of secondary pre-service teachers, there are some limitations to consider. First, a case study design is used to provide rich detail regarding two pre-service teachers. The study, then, may not be generalizable to all secondary pre-service teachers. Instead, this study will add to the growing body of literature to help create a more robust picture of the instructional practices of pre-service teachers. A second limitation is that the two participants in the current study are teaching related, yet different mathematics content. Therefore, it may be the case that the observed instructional practices may differ based on the course content.

1.9 ORGANIZATION OF THE DOCUMENT

This document is organized into five chapters. This first chapter provided an overview of the study, including a discussion of the larger context of mathematics education reform and implications of how the current study will add to the current literature base. The second chapter examines in more depth the literature relevant to this study. In particular, research relating to the use of cognitively demanding tasks, representations of mathematical concepts as tools to aid understanding, and normative practices in reform-oriented classrooms will be examined. In addition, research relating to pre-service teacher education and instructional practices will also be described. Chapter three delineates the methodology of the study, including the larger context of the study, the participants, data sources, and analysis procedures. Chapter four presents the results from the analysis of the data. Chapter five is comprised of a discussion of the results and of conclusions drawn from the results.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

This study seeks to describe the nature of the instructional practices of two secondary mathematics pre-service teachers. That is, the study aims to examine the pre-service teachers' selection and implementation of tasks, the availability and use of tools, and the normative practices. In addition, factors that appear to influence the instructional practices will also be explored. Three main bodies of relevant literature will be discussed in this chapter. First pertinent studies regarding the critical dimensions of instructional practices (i.e., tasks, tools, and norms) are reviewed. Specifically, literature on the cognitive demands of tasks is discussed. In addition, this study focuses on a particular tool as support for student learning-- representations of functions. Therefore, research regarding the role of representations and pre-service teachers' understanding of representations of functions is discussed. A critical norm of student centered classrooms is discussions that focus students on developing meaning for the mathematics. In order for such discussions to occur, the teacher must find ways to assess and advance the students' understanding. One method to accomplish this goal is through questioning. Consequently, literature related to questioning and its impact on student learning is also explored. The second body of literature reviews studies regarding teachers' use of ROC and factors that affect the use of the ROC. The third section draws on the literature about pre-service teacher education projects that sought to support pre-service teachers in thinking about and implementing reform-oriented instructional practices. Finally, the chapter ends by addressing the implications of the literature for the current study.

2.2 CRITICAL DIMENSIONS OF INSTRUCTIONAL PRACTICE

2.2.1 Tasks

The academic work students do in a classroom is dependent upon the tasks in which they engage (Doyle, 1983). Doyle defines tasks "by the answers students are required to produce and the routes that can be used to obtain these answers" (p.161). To that end, Doyle identified four types of general academic tasks: 1) memory tasks, 2) procedural or routine tasks, 3) comprehension tasks, and 4) opinion tasks. Each of these types of tasks requires a different type of thinking from students, thus resulting in different types of learning. For example, both memory and procedural tasks involve students reproducing given information. Little, if any, understanding is needed to be successful on such tasks. In contrast, comprehension tasks require a deeper level of knowledge that involves understanding the concepts that underlie the task.

Traditionally, the general curriculum in schools in this country has included more tasks that focus on routinized basic skills and procedures than on comprehension and opinion, which are fundamental for understanding (Findell, 1996; Stanic & Kilpatrick, 1992; Resnick & Resnick, 1992). Data from TIMSS indicate that eighth-grade students in this country are not exposed to quality mathematics that prompt thinking and reasoning. In fact, 89% of the lessons from the United States were rated as having a low quality of mathematics, and no lesson was rated as being high quality. This stands in contrast to the Japanese and German counterparts in which only 11% and 34% of the lessons were rated as low quality, respectively (Stigler & Hiebert, 1999).

Today's students need to go beyond a curriculum comprised of tasks that focus primarily on memorization and rote skills towards a "thinking curriculum" that is designed to prepare students for the challenging demands of our increasingly complex society (Resnick & Resnick, 1992). A critical focus of the reform in mathematics education is shifting emphasis from "drill and skill" tasks to challenging and worthwhile tasks (NCTM 1989, 1991, 2000). This section examines relevant literature regarding the use of tasks in mathematics classrooms.

2.2.1.1 Tasks at the elementary level Hiebert and Wearne (1993) examined two facets of the instructional practices of all the second-grade math classrooms (total of 6) in one rural/suburban school: tasks and discourse. The classrooms were selected for study since there was a large enrollment. At the beginning of the school year, each of the 147 students was assigned to a mathematics classroom based on their comparative rank on a teacher-constructed skills and facts test. The 60 students who scored highest were grouped into two higher tracks (classrooms E & F), while the remaining students were randomly distributed across the remaining four classrooms (classrooms A, B, C, and D). Observations spanned the course of the year, but occurred during units on place value, multidigit addition, and multidigit subtraction.

Two of the six classrooms in the study, classrooms D and F, received "alternative instruction" during the observations in the units described above. The purpose of the alternative instruction was to provide students with opportunities to "construct relationships-- relationships between their current knowledge and new information, relationships between different forms of representation, and relationships between alternative procedures" (p.398). The project, however, employed two experienced elementary teachers to implement the alternative instruction rather than using the regular classroom teacher. This was done to try to ensure a more faithful implementation of the alternative instruction lessons. The method and the tasks used in these classrooms stand in sharp contrast to the conventional method and tasks of the second-grade textbook used in the other four classrooms in that the focus in the alternative instruction classrooms was on "constructing relationships between place value and computation strategies rather than practicing prescribed procedures" (p.393).

Written assessments were administered to all students at the beginning and end of the project. The results of the task analysis will be discussed here, while the results of the discourse analysis will be discussed in a later section.

In examining the nature of the tasks used in the classrooms, nine lessons from each of the six classrooms were selected for consideration. All tasks from each lesson were coded in two ways. First, tasks were coded with respect to the mathematical content, distinguishing between "problems that involved place value ideas but did not require conventional computation and computation problems" (Hiebert & Wearne, 1993, p.406). Then, tasks were coded for the contextual features. The context of the task was identified as one of the following five categories: "(a) problems presented and solved using only written symbols; (b) problems presented using pictures or diagrams; (c) problems solved with the aid of physical materials; (d) problems presented through a story and solved using paper and pencil only; and (e) problems presented through a story and solved with the aid of physical materials" (p.406-407).

Results for the content analysis did not show any strong differences between each of the six classes regarding both the emphasis on place value and the number of problems actually completed. However, strong profiles emerged regarding the contextual features of the tasks used. While there were slight differences between each classroom, two distinct categories were noted. The tasks in classrooms A, B, and C emphasized the use of written symbols and procedures whereas the tasks in classrooms D, E[1], and F focused on concepts and were situated in story problems. These profiles that emerged with respect to the contextual features of the task proved to be a critical factor when examining student achievement. The results indicated that tasks that focused on concepts and used multiple representations seemed to positively impact student learning.

2.2.1.2 Tasks at the middle school level: The QUASAR Project QUASAR was a national project that sought to "demonstrate the feasibility and responsibility of designing and implementing meaning-oriented, high-level instructional programs" in middle school classrooms in economically disadvantaged schools where prior instruction typically focused heavily on mastering procedures (Stein & Lane, 1996, p.53). The six schools involved in the project differed with respect to "size, geographic location, and ethnic make up of their student populations" (p.53). Most of the teachers involved in the project were elementary certified, and their experience ranged from one to twenty years of teaching, with an average of 13 years (Stein et al, 1996). Each of the QUASAR schools received support from resource partners at a local university as well as the project staff as the teachers worked to develop instructional practices that provided students with opportunities to think and reason about mathematics (Stein & Lane, 1996).

One facet of instructional practices that the QUASAR team investigated was the cognitive demands of the tasks used in the classrooms. According to Stein, Grover, and

[1] Although classroom E was not one of the alternative instruction classrooms, the profile that emerged with respect to the instructional tasks (i.e., number of problems, time spent per problem, contextual features of problems, and time spent on class discussion) tended to consistently fall between the extremes of classrooms A, B, C and classrooms D, F.

Henningsen (1996), tasks can be generally classified as either requiring a high-level of cognitive demand (i.e., procedures with connection to meaning or doing mathematics) or a low-level of cognitive demand (i.e., memorization or procedures without connection to meaning) from the students. *Procedures with connections* and *doing mathematics* tasks focus students' thinking on developing meaning for the underlying mathematics of the task. For example, tasks of this character may require that students solve a problem in multiple ways or make connections between representations. In contrast, both *procedures without connections* and *memorization* tasks focus students' thinking on reproducing previously learned material such as facts or procedures and do not require that students make connections to meaning.

Building on Doyle's (1983) notion of different types of tasks, Stein et al (1996) developed a framework (see figure 1) for analyzing the cognitive demands of a mathematical task as the task progresses through three phases. The first phase of the framework examines the task as it appears in the curriculum or instructional materials. Next, the task is again analyzed as the teacher sets-up or introduces the task in the classroom. The third phase, implementation, examines the "*cognitive processes in which students actually engage* as they go about working on the task" (Stein et al, 1996, p.461). According to the framework, the cognitive demands of a task can change between each of the phases. The QUASAR research (Stein, Grover, & Henningsen, 1996; Henningsen & Stein, 1997) examined the cognitive demands of tasks at the set-up and implementation phases of the framework and the factors that influenced the maintenance or decline of the demands during the enactment of the lesson.

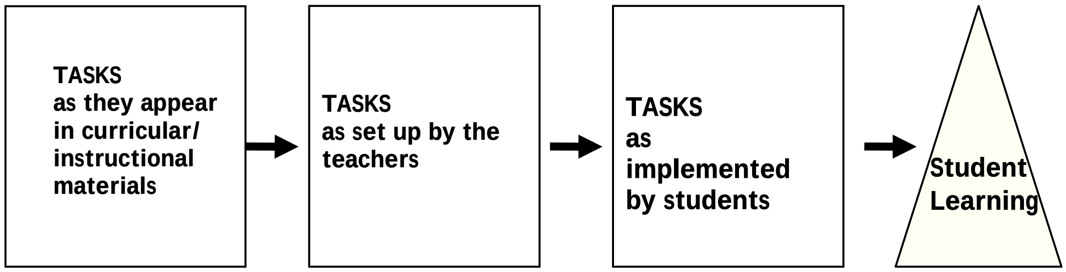


Figure 1. The Mathematical Task Framework (Stein et al, 1996)

In a study of 144 tasks, Stein et al (1996) analyzed the characteristics of tasks (i.e. source, topic and context), the features of tasks at set-up (i.e., solution strategies, representations, communication) cognitive demands at the set-up, and the features and cognitive processes used by the students during implementation. The authors found that most tasks were created by the project participants (39% of the tasks) and or found in reform oriented curricula (30% of the tasks). The remaining tasks were taken from various resource books (19% of the tasks) or the classroom textbook (11% of the tasks)[2]. At set-up, approximately two-thirds of the tasks allowed for multiple solution paths, promoted the use of multiple representations, and required an explanation; all features that are in line with the tenants of the reform. In addition, nearly three-fourths of the tasks were set-up with high-level cognitive demands. In other words, the project teachers were selecting and setting-up tasks in a way that had the potential to provide students with the opportunity to think and reason in ways that could build and strengthen their conceptual understanding of the mathematics of the lesson.

During the implementation, the features of the tasks (i.e., multiple solution paths, multiple representations, and explanations) stayed relatively consistent. That is, tasks that allowed for multiple solutions tended to generate such and tasks that required an explanation

[2] ROC were being developed during the time of the QUASAR project and therefore were not as readily available as now.

tended to have one produced. However, these features alone do not indicate the extent to which the cognitive demands of the lesson were maintained. While a high percentage of procedures without connections tasks were maintained (96%), this was not true of the tasks set-up at high levels of cognitive demand. Approximately half (53%) of the tasks set-up as procedures with connection were not maintained because there was no connection made to the underlying concepts of the task. Similarly, only 38% of the tasks set-up as doing mathematics were maintained. The findings indicate that as students engage with cognitively demanding tasks, “it appears fairly easy for students to slip into the rote application of formulas and algorithms” (Stein et al, 1996, p.476).

Each lesson in which the task declined from high-level at set-up to low-level during implementation (61 tasks) was further analyzed for factors that appeared to influence the decline in cognitive demands. The researchers identified six factors. The first factor, challenges become nonproblems, was the most commonly identified reason for a decline (64%). This occurred when the teacher did the thinking on the task rather than allowing the students to grapple with the mathematics. For example, a teacher may provide students with the procedure to follow in order to reduce the ambiguity of the task or the anxiety level of the students. The second factor is the inappropriateness of the task for students. This factor was selected in 61% of the lessons for a variety of reasons, including motivation and students’ prior knowledge. The third factor, focus shifts to correct answer, was identified in 44% of the lessons. A fourth factor noted that in 38% of the lessons that declined the students were given too much or too little time to effectively engage with the task. Students’ lack of accountability to engage with the task at high-levels was cited as a factor in 21% of the lessons. Only 18% of the lessons declined as a result of classroom management problems. Overall, approximately 2.5 factors were identified for each lesson in which the cognitive demands declined (Stein et al, 1996; Henningsen & Stein, 1997).

The researchers also identified factors associated with the maintenance of the cognitive demands from set-up through implementation. Interestingly, an average of four factors for each lesson were identified. The most common factor was that the task built on students' prior knowledge (82%). Allowing the appropriate amount of time and modeling of high-level performance by either the teacher or a student both were cited in 71% of the lessons. Continually pressing for explanations, justifications, and meaning was a factor in 64% of the lessons. Scaffolding in a way that supported students' engagement with the task without removing the challenging aspects was identified as critical in 58% of the lessons. The final two factors in maintaining the high-level demands of the task were student self-monitoring (27%) and the teacher drawing conceptual connections (13%) (Stein et al, 1996; Henningsen & Stein, 1997).

An analysis of the set-up and implementation of tasks as they related to student learning gains on the QUASAR Cognitive Assessment Instrument (QCAI) at the four QUASAR sites provides evidence that the thinking required of the students during the implementation of the lesson does impact students' understanding and learning. Of the four QUASAR sites, site A had the highest learning gains, site D the lowest, and sites B and C in the middle. Stein and Lane (1996) examined the patterns of task set-up and implementation across each site to determine if a relationship existed between the cognitive demands of the lessons and student learning gains on the QCAI.

Indeed, the tasks at site A tended to be consistently set-up and implemented at high-levels, with a majority of tasks set-up at the "doing mathematics" level of cognitive demand. In contrast, about half the tasks at site D were set-up with low-levels of cognitive demand and all but one of the tasks set-up at a high-level of cognitive demand declined in the thinking required of the students. Sites B and C also used a large number of high-level tasks, but unlike site A, these tasks were more even distributed between "doing mathematics" tasks and "procedures with connections" tasks. Of these tasks, less than half were implemented in a way that maintained the level of cognitive demand; specifically, only 43% of the tasks at site B and 33% of the tasks at site C remained high-level as the students engaged with the task.

Student learning gains were highest when the tasks were consistently set-up and maintained at a high-level of cognitive demand and lowest when the tasks were set-up and implemented at a low-level. Interestingly, moderate learning gains were associated with tasks that were set-up at a high-level, but were implemented inconsistently. That is, even if the tasks weren't all implemented to the full potential, it appears that students still benefited from being exposed to tasks that provide opportunities to think and reason (Stein & Lane, 1996).

2.2.1.3 Tasks at the middle school level: The TIMSS Video Study The TIMSS Video Study was first conducted in 1995 and represented the first time that video was used to examine teaching practices at such a large scale (NCES, 2003). The project had three goals:

1) to learn how eighth-grade mathematics is taught in the United States;
2) to learn how eighth-grade mathematics is taught in the two comparison countries; and
3) to learn how American teachers view reform and to see whether they are implementing teaching reforms in their classrooms (Stigler & Hiebert, 1997).

Germany and Japan were chosen as the two comparison companies since they were both economic competitors of the U.S.; Japan was also chosen since the students' scores from Japan were consistently among the top scores. A random subsample of the original TIMSS classrooms was selected for videotaping, with the final sample including 81 classrooms in the U.S., 50 in Japan, and 100 in Germany. One lesson from each classroom was videotaped.

The results from the study found that U.S. students were not engaging in the same level of mathematics as countries such as Germany and Japan; that is, the tasks that students were engaging with in the U.S. did not provide the same opportunities for students to think and reason as did the tasks in Germany and Japan. For example, almost 90% of the U.S. lessons observed were coded as having low quality of mathematical content, compared to only 11% in Japan and 34% in Germany (Stigler & Hiebert, 1999). This is further illustrated when the focus of the lesson is examined. In both Germany and Japan, approximately 80% of mathematical concepts were developed in a way that allowed students to think and reason about the mathematics. In contrast, only 20% of the concepts were developed in the U.S., with the remaining 80% of concepts being stated. Additionally, the study described the kinds of tasks the students worked on during seatwork using three categories: practicing procedures, applying concepts, or inventing/thinking/analyzing.   Japan had the most even balance between the three categories, with approximately 40% of the tasks focused on procedures, 15% focused on applying procedures in a novel situation, 45% of the tasks focused on analyzing new situations or creating new procedures. This is in stark contrast to the U.S., where approximately 96% of the tasks students worked on involved practicing routine procedures, and less that 1% of the work engaged students in analyzing the mathematics (Stigler & Hiebert, 1997; 1999).

A second video study was conducted in 1999. This study built on the ideas and methods of the 1995 study, but expanded the participating countries to include Australia, the Czech Republic, Hong Kong SAR, the Netherlands, Switzerland, and the United States. Although Japan did not participate in the 1999 study, the videos from the 1995 study were analyzed again and included in the results (NCES, 2003). The portrait of mathematical instruction in the U.S. from the 1999 study is similar to the 1995 study. Approximately 67% of the lessons were identified as low-level complexity, meaning that students were able to solve the problem with few steps (less than four) and little reasoning. Only 6% of U.S. lessons were identified as high-complexity. The majority of tasks required students to use procedures (69%) or state concepts via providing an example (13%), while only 17% of the tasks prompted students to think, reason, and make connections to the underlying mathematics. Similar to the 1995 portrait, Japan's lessons focused on analyzing, thinking, reasoning, and developing concepts. Only 17% of the Japanese lessons analyzed in the 1999 study were categorized as low-level complexity. Additionally, 54% of the tasks were focused on making connections (NCES, 2003).

Japan's average mathematics scale score was 89 points higher than the U.S. in 1995 (581 and 492, respectively) and 77 points higher in 1999 (579 and 502). One explanation for the differences in the scores could be the level of mathematical tasks that students in each country are exposed. The overall focus of mathematics lessons in the U.S. was on memorizing and performing procedures instead of developing concepts, where as Japan classrooms tend to focus more on developing concepts.

2.2.2 Tools: Representations

Tools can support students as they engage with tasks in that the tools provide a way for students to explore the mathematics in a task, record their thinking, and discuss their thinking and reasoning with others (Carpenter & Lehrer, 1999; Hiebert et al, 1997). The meaning and impact of a particular tool can only be developed by the students as they use the tool; that is, "meaning developed *for* tools and meaning developed *with* tools both result from actively *using* tools" (Hiebert et al, 1997, p.55). One particular tool that is useful in providing students with opportunities to think, record, and communicate about mathematical concepts is representations. Representations allow students to focus on how the same mathematical concept can be represented in various forms (i.e., context, manipulative models, pictures/diagrams, spoken language, and written symbols) and also provide a variety of ways to document and communicate about a student's thinking and reasoning on a task.

A review of the literature on mathematical representations presents various yet related definitions of the term representation. The definitions can be separated into three categories: internal, external, and object-oriented. An internal representation involves a student's mental organization of a mathematical concept or process (Pape & Tchoshanov, 2001; Goldin, 2003). By their nature, internal representations are not directly observable. As a result, more emphasis is placed on external representations, which are the visible and observable materialization of a student's cognitive schemata of the mathematical concept (Goldin & Kaput, 1996; Lesh, Post, & Behr, 1987; Pape & Tchoshanov, 2001). For example, written numerals and a grouping of blocks are an external representation of a student's internal schema of counting and numeracy. The external and internal components of representations are directly connected; however, the external representations are only valuable if they correspond meaningfully with a person's internal representations (Goldin & Kaput, 1996). Greeno & Hall (1997) warn that there is a difference between the potential and actual representations in that the external component is only a true representation of a student's internal schemata of a concept if the student interprets the representation in such a way to give it meaning. For example, a 3x3 array is only an external representation of a multiplication concept if the student is able to interpret the array in a meaningful way.

According to the NCTM (2000), “the term *representation* refers both to process and to product—in other words, to the act of capturing a mathematical concept or relationship in some form and to the form itself” (p.66). This definition builds on the interconnectedness of the internal and external notions of representation. Smith’s (2003) definition also focuses on this connection. He characterizes representation as the combination of a student’s mental construction of an idea with any physical representation used to display or communicate that understanding. While these definitions have potential to provide a complete picture of a student’s understanding, one disadvantage is the need to rely on the external representation as the indicator of a student’s internal representation or understanding.

Brinker (1996) broadens the idea of external representation beyond student-created representations to also include structured or instructional materials, such as algebra tiles and pre-printed worksheets. While Brinker’s definition still includes “students’ notations and pictures” (p.1), his focus is only on the form of the product rather than what the product may represent mentally for the student. Smith (2003) refers to this as an object-oriented definition because the focus is removed from the student and placed on the “physical embodiments” of the concept (p.264).

Brinker’s (1996) definition is advantageous in that a small number of categories can be created to classify representations with little ambiguity. For the purposes of the current study, Brinker’s definition of representation will be used. The representation may be constructed by the teacher or student either prior to or during a lesson. For example, a graph on a worksheet as well as a graph spontaneously drawn by a student both constitute the use of a graphical representation. The following sections more closely examine how representations are used in classrooms.

2.2.2.1 The importance of representations The overall goal of classroom instruction is for students to develop an understanding of various mathematical concepts. Research indicates that a critical factor in a student's understanding is recognizing a mathematical concept in various representations and being able to flexibly move between these representations (Lesh, Post, & Behr, 1987; Dreyfus & Eisenberg, 1996). A representation of some form must be used to state or convey a mathematical concept (Dreyfus & Eisenberg, 1996). Emphasizing the use and connections among various representations, though, is different from the traditional teaching of mathematics (Clark, 1997; Carroll, Fuson, & Diamond, 2000; NCTM, 2000). Traditionally, students engage primarily in maneuvering within only one representation, namely, written symbols (Carroll, Fuson, & Diamond, 2000). This concentration on only one representation limits students' ability to develop conceptual understanding (Pape & Tchoshanoz, 2001). Instead, students need to explore and analyze various forms of a mathematical concept in order to develop firm associations between representations and be able to navigate through the representations (Dreyfus & Einsberg, 1996; Greeno & Hall, 1997). This, in turn, will provide students with "a set of tools that significantly expand their capacity to think mathematically" (NCTM, 2001, p.67).

To that end, key reform documents such as the PSSM (NCTM, 2000) are drawing attention to the need to expand the use of multiple representations in mathematics classrooms at all grade levels. One of the five process standards in the PSSM is representation. This standard states that all students must be able to

- create and use representations to organize, record, and communicate mathematical ideas;
- select, apply, and translate among mathematical representations to solve problems; and
- use representations to model and interpret physical, social, and mathematical phenomena (NCTM, 2000, p.67).

Pape and Tchoshanov (2001) note that the recognition of representation as a separate process standard is significant and characteristic of the growing interest among researchers in the role of representations in the mathematics classroom.

Lesh, Post, and Behr (1987) identify 5 types of general mathematical representations: 1) experience-based scripts, 2) manipulative models, 3) pictures/diagrams, 4) spoken language, and 5) written symbols. Each representation is independently important since each focuses a student's attention on separate characteristics of the underlying structure of the concept (Lesh, Landau, & Hamilton, 1983; NCTM 2000). Again, though, it is a student's ability to move fluidly between representations that demonstrates a solid understanding of the concept (Lesh, Landau, & Hamilton, 1983; Lesh, Post, & Behr, 1987; Pape & Tchoshanov, 2001). This requires that teachers provide students with a variety of ways to think about and explore a concept, thus allowing the students the opportunity to create an integrated web of understanding around that concept.

2.2.2.2 A specific example: Representations of functions One particular area of focus is the literature surrounding the use of different representations of functions. The emphasis on understanding functional relationships across the grades has continually increased over the past two decades (Leinhardt, Zaslavsky, & Stein, 1990; NCTM, 2000). In fact, Dubinsky (1993) argues, "functions form the single most important idea in all mathematics, at least in terms of understanding the subject as well as for using it" (p.527). Understanding functions involves being able to translate between graphs, equations, real-world contexts, tables, and language (Van de Walle, 2004).

Students do not, however, spontaneously make connections between different representations. Knuth (2000) examined high-school students' ability to connect equations and graphs; more specifically, he sought to see if students could see "the connection that the coordinates of any point on a line will satisfy the equation of the line" (p.502). Of the 178 students in the study, 44 were in algebra one, 19 in geometry, 65 in algebra two, 32 in precalculus, and 18 in advanced placement calculus. Each of the student participants were given one of six problems that had both an equation and graphical representation of a specific function. For example, one task asked if it is possible to find a solution to the given equation in which the coefficient of one variable was unknown. Knuth found that students relied on the equation representation to solve over 75% of the tasks, even when using the graphical representation was more efficient. In trying to explain the underlying cause of this phenomenon, Knuth points to the classroom instruction as the greatest influence. He claims that manipulating equations overshadows instruction in the typical high school mathematics classrooms. As a result, students do not see other representations as meaningful or useful. This reinforces the work of Leinhart et al (1990). In reviewing the literature on the tasks and teaching of functions, they found that students are predominately exposed to tasks that focus on translations from the equation to the graph.

Studies with pre-service secondary mathematics teachers reveal a similar trend in that the pre-service teachers also struggle with moving flexibly between different representations of functions, which in turn, impacts their instructional practices (Even, 1993, 1998; Sanchez & Llinares, 2003; Wilson, 1994). Even (1998) studied 152 pre-service secondary mathematics teachers. Similar to Knuth's (2000) finding, the participants in Even's study relied heavily on manipulating equations to solve a given problem. For example, on one problem only 14% of the participants correctly solved the problem. A notable finding is that those who solved the problem correctly also created graphical representation to solve the task. Over 80% of the pre-service teachers relied only on the equation representation and were unable to solve the problem.

Wilson (1994) more explicitly explored the development of one pre-service teacher's understanding of functions as she progressed through a mathematics education course, of which the second half of the course focused on functions. Molly, a junior in college, had a strong interest in mathematics and had taken a variety of mathematics and mathematics education courses prior to her enrollment in the methods course. Wilson traced changes in both Molly's content knowledge and pedagogical choices throughout the term. Of particular importance was Molly's understanding of different representations and how that understanding influenced her thinking about the teaching of functions.

At the beginning of the course, Molly had a limited view of functions, and was not able to make meaningful connections between the various representations. In one interview she was presented with cards that each had a different representation, such as a table, graph, or equation. Molly was asked to sort the cards in some way. She first chose to sort by representation (i.e., put all the graphs together); however, when pushed to do it again, Molly struggled to see how some of the cards were different representations of the same function. For example, while examining a table of values she stated that the values were "'just ordered pairs, you really don't know anything about them…. You don't know if x is squared, or if y is half of x"' (p.357). In addition, she did not connect the real-world contexts to any other representation in the card sort activity. The same was true when she was specifically asked to solve a contextualized problem. Rather than developing an equation or sketching a graph, she would work through a series of computations.

As the course progressed through the functions unit, Molly's understanding of the concepts began to change. The course provided her with opportunities to strengthen her ability to move between the representations. At the end of the course, she was able to generate an equation and a table for a real-world situation, as well as see how the three representations were related.

Sanches and Llinares (2003) examined how a pre-service teacher's knowledge of functions influences the teacher's pedagogical choices. One specific focus was on the pre-service teacher's use and understanding of multiple representations and how that impacts instructional decisions. Each of the four participants (Jose, Juan, Rafael, and Alberto) had degree in mathematics (or its equivalent) and were enrolled in a general methods graduate course, of which approximately 17% of the course was devoted to issues in mathematics education. The pre-service teachers were also involved in a tutoring program in a secondary mathematics classroom under the direction of the classroom teacher.

Through a series of four interviews that focused on gaining insight into each pre-service teacher's beliefs about teaching, knowledge of functions, and pedagogical content knowledge about functions, Sanches and Llinares (2003) determined that the pedagogical choices each pre-service teacher made were linked to his own understanding of functions. With respect to representations, both Juan and Rafael relied primarily on equations when solving problems, seeing the use of equations as the best method to solve any task. While planning a hypothetical set of lessons on functions, both Juan and Rafael used tasks that emphasized equations and computation. In contrast, Jose and Alberto used tasks with a larger variety of representations in meaningful ways. For example, both "incorporated the use of graphs as an 'instrument' for solving real situations" (p.21).

2.2.2.3 Cautions with representations Research indicates, however, that even when students are frequently exposed to various representations, the importance of these representations is often underestimated and treated superficially (Boulton-Lewis, 1998; Kaput, 1987). In some instances, the representations as well as the relationships between them are not explored in a meaningful way. For example, students may be taught a mathematical procedure such as using the point-slope formula without meaningfully connecting the symbolic notation to other representations such as a graph. By the same token, “real-world” situations are often created in ways that may not be meaningful to the students. This, in turn, limits students’ abilities to connect their existing knowledge and experiences with the mathematics in the problem (Leinhardt, 1988).

The power of representations is also undermined when the goal of the lesson centers on the superficial use of representations rather than viewing the representations as a vehicle for developing understanding (Greeno & Hall, 1997; NCTM, 2001; Pape & Tchoshanov, 2001). For example, teachers often use concrete manipulatives under the assumption that the use of such materials alone will aid in the students developing a deeper understanding of the mathematical concept (Boulton-Lewis, 1998); however, student’s may not independently make meaningful connections between the representation and the mathematical concept which it represents (Leinhardt, 1988; Pape & Tchoshanov, 2001).

Therefore, teachers play a vital role in influencing students’ mathematical thinking, reasoning, and ultimate understanding. Lesh, Post, and Behr (1987) found that “successful teachers” structure the class to aid students in developing connections between representations. This structuring involves both the selection of the task and organization of the related mathematical discussions. As previously discussed, the task a teacher selects impacts students’ opportunities to think mathematically and make connections between representations. In addition, teachers need to engage students in quality mathematical discussions that focus on the use of various representations (Dreyfus & Einsberg, 1996; Greeno & Hall, 1997; Carroll, Fuson, & Diamond, 2000). One vehicle for developing such conversations is by asking students questions that promote mathematical thinking.

2.2.3 Normative Practices: Questioning

Discussions around mathematical concepts should be a normative practice of a mathematics classroom since this type of talk "helps build meaning and permanence for ideas and makes them public", which then allows for others to reflect on and learn from what was said (NCTM, 2000, p. 60). According to Newton (2002), the talk in a classroom can support students' learning by connecting to their prior knowledge and experiences, and pushing the students to make meaningful connections. Additionally, the talk in a classroom provides the teacher with a way to assess the students' understanding (Newton, 2002). Various studies (e.g., Chapin et al, 2003; Lampert & Rittenhouse, 1996; Forman et al, 1998; Martino & Maher, 1999; O'Connor, 2001) indicate that talk in a mathematics classroom is a critical factor in conceptual learning.

Additional studies (Kieran, 2001; Sfard & Kieran, 2001), however, point to the fact that students may struggle to communicate on their own. That is, without effective prompts, it may be challenging for students to describe and discuss their thinking and reasoning in a productive way. An important role of the teacher, then, is to facilitate meaningful mathematical discussions. These discussions may occur between the teacher and student, a small group of students, or a full class conversation. In order to facilitate such discussions, the teacher needs to assess students' knowledge of the concept being explored, understand the students' thinking and strategies, prompt students to make mathematical connections (i.e., between representations, to prior knowledge, etc), and push students to think and reason beyond their current understanding. Questioning is an effective means to promote such activities. This section describes four studies that examined the use of questioning in both classroom and student interview settings.

In analyzing the discourse in six second grade classrooms, Hiebert and Wearne (1993) identified four basic types of questions teachers asked during whole group discussions. The differences in the categories revolves around the "the amount of self-explanation and the kind of cognitive activity they elicit" (p. 403). The first type was recall. The second type, describe strategy, asked students to either explain their thinking on a problem or to provide an additional method to the problem at hand. The third type of question, generate problem, prompted students to construct a problem given a number sentence or other conditions. The final type, examine underlying features, focused students' attention on the mathematical concepts of the problem. Questions of this nature typically asked for a conceptual explanation or a deeper analysis of the problem or solutions.

After finalizing the question categories, two lessons from each of the six classrooms were then randomly selected for further analysis. One prominent difference between classrooms that emerged was the use of different question types. While results indicated that most of the questions asked in all of the classrooms were focused on recall, the average percent of recall questions asked in each lesson ranged from approximately 49.5% in classroom F to 96% of all questions in classroom B. In addition, the teachers in classrooms D and F (both of the alternative instruction classrooms) both asked a number of additional questions from the remaining categories. Of the questions the teacher in classroom D asked per lesson, approximately 15% were describe strategy questions and 21% were examine underlying features questions. Similarly, of the questions teacher in classroom F asked, an average of approximately 28% of the questions asked students to describe a strategy and 22% of the questions focused on examining the underlying features. Less than one percent of the questions asked in classrooms D and F asked students to construct a story or problem.

This diversity in questions stands in stark contrast to the types of questions asked in classrooms A, B, and C. The overwhelming majority of questions in each classroom were of the recall type: 92% in classroom A, 96% in classroom B, and 95% in classroom C. The remaining questions in classroom A involved describing strategies (2.7%) and examining the underlying features (5.2%). In addition to the recall questions, the teacher in classroom B only asked questions that focused on the underlying features (4%). The teacher in classroom C did ask questions of each type- approximately 2% of the questions were describing, 2% generating stories, and the remaining 1% asked about the underlying features of the task. As with the profile that emerged for the tasks used, classroom E fell between the two extremes with respect to the questions asked. The teacher asked a range of questions (i.e., 81.6% recall, 4.2% describing, 5.5% generating, and 8.7% examining underlying features). The percentages of each type of question fell between classrooms A, B, and C and classrooms D and F.

The researchers further explored the relationship between the types of questions asked and student learning. At the beginning and end of the year, the students in each school were assessed on place value and computation knowledge with a written assessment. A comparison of the results from each assessment provides insight into the impact of the differences in the question types used in the classrooms as described above. At the beginning of the year, classrooms A, B, C, and D clustered together as did E and F, with the latter having higher scores. At the end of the year, classrooms A, B, and C were still clustered together while classrooms D, E, and F now clustered together with scores higher than the other cluster. The findings indicate that the types of questions asked, as well as the tasks used, does in fact impact student learning. The classrooms that had the highest student learning gains were those in which a greater variety of questions were asked.

Boaler and Brodie (2004) examined instructional practices of teachers in three high schools. Two of the high schools, Hilltop and Greendale, provided students with a choice between a traditional mathematical sequence and curriculum (i.e., algebra, geometry, and advanced algebra) and the reform-oriented curriculum Integrated Mathematics Project (IMP). The third school, Railside, used a teacher constructed curriculum that the researchers classified as reform-oriented since it was exploratory in nature and focused on developing and understanding concepts rather than just following prescriptive procedures. The study focused on seven teachers, 2 from Hilltop and Railside and three from Greendale. Two of the teachers from Greendale and one from Hilltop used IMP. One teacher from Hilltop and one from Greendale each used a traditional curriculum.

One aspect of the analysis focused on the questions asked in the classrooms. After reviewing various teaching episodes, the researchers identified nine types of questions asked in mathematics classrooms (see figure 2). The results indicated the types of questions asked were related to the curriculum used in the classroom. Nearly all (97% and 99.5%) of questions asked in the classrooms using a traditional text were of type 1; that is, purpose of the question was "gathering information [or] leading students through a method" (p.776). The teachers using a ROC also asked a large percentage of type one questions (i.e., 71%, 69.5%, 63.5%, and 61%); however, these teachers also asked a variety of additional questions that focused on assessing and advancing students' understanding. These questions (types 3-9), provided opportunities for students to compare and analyze their solutions, make generalizations, and communicate their thinking and reasoning to the teacher and other students. Boaler and Brodie (2004) also note that the types of questions asked by the teacher seem to influence the types of questions students ask of themselves and their groups. In analyzing the IMP classrooms, the researchers found that the students also learned to ask conceptually oriented questions. For example, one group knew that the teacher would press them to justify where the number in their solution came from, so one student asked, “’Where did we get it?’”(p.780).

Question Type	Description	Examples
1. Gathering information, leading students through a method	Requires immediate answer Rehearses known facts/procedures Enables students to state facts/procedures	What is the value of x in this equation? How would you plot that point?
2. Inserting terminology	Once ideas are under discussion, enables correct mathematical language to be used to talk about them	What is this called? How would we write this correctly?
3. Exploring mathematical meanings and/or relationships	Points to underlying mathematical relationships and meanings. Makes links between mathematical ideas and representations	Where is this x on the diagram? What does probability mean?
4. Probing, getting students to explain their thinking	Asks students to articulate, elaborate or clarify ideas	How did you get 10? Can you explain your idea?
5. Generating Discussion	Solicits contributions from other members of class.	Is there another opinion about this? What did you say, Justin?
6. Linking and applying	Points to relationships among mathematical ideas and mathematics and other areas of study/life	In what other situations could you apply this? Where else have we used this?
7. Extending thinking	Extends the situation under discussion to other situations where similar ideas may be used	Would this work with other numbers?
8. Orienting and focusing	Helps students to focus on key elements or aspects of the situation in order to enable problem-solving	What is the problem asking you? What is important about this?
9. Establishing context	Talks about issues outside of math in order to enable links to be made with mathematics	What is the lottery? How old do you have to be to play the lottery?

Figure 2. Categories of questions (Boaler and Broodie, 2004, p.776)

Martino and Maher (1999) found that the timing of a question as well as the purpose of the question itself is a critical factor on the impact of the question on student learning. The study describes how one teacher influenced the learning of 3 students (two third graders and one fourth grader) through the use of well-timed questions that prompted the students to justify, re-organize, and generalize their solutions to two problems. The researchers state that prior to the teacher interacting with the students, the "students indicated satisfaction with their original solutions obtained by trial and error methods" (p.74). As the teacher asked the students to compare solutions and justify their responses, the students often restructured and expanded their thinking on the problems. For example, after Meredith and Jackie completed the tower problem[3], the teacher asked, "How do you know you don't have any (towers) in here that are the same?" (p. 61). Although the students had the correct solution, this question prompted the students to find a method to reorganize their thinking in a way that would be more convincing.

Martino and Maher (1999) claim that effective questioning is an "art" that develops over time. One point in time that is critical point for building a strong foundation for questioning is in pre-service teacher education programs. To that end, Moyer and Milewicz (2002) examined 48 elementary pre-service teachers' questions while interviewing a student about fraction concepts as a part of their math methods course. The students interviewed spanned the K-6 grade levels. Prior to conducting the interviews with students, the pre-service teachers watched a videotape of an interview with two second-grade students. The purpose of the activity was to provide the pre-service teachers with the opportunity to analyze the questions asked by the interviewer to determine the effectiveness of the question on assessing students' understanding of the concepts.

[3] According to Martino and Maher (1999), "the task required students to build as many towers as possible of a certain height (for example, all possible towers four cubes tall) when plastic cubes (Unifix cubes) in two colors were available" (p.59)

The pre-service teachers were then provided a protocol that included tasks and sample questions to use during the completion of the interview assignment.

A review of the transcripts of each of the interviews revealed patterns of questioning techniques used by the pre-service teachers. Moyer and Milewicz (2002) distinguished three categories. The first, checklisting, involved reading the questions in order directly from the protocol with no follow-up questions. The student's response seemed to be of no use to the pre-service teacher.

The second category was "instructing rather than assessing". Unlike checklisting, this category did involve using the student's responses; however, the follow-up questions posed were focused on the students getting the right answer rather than attending to student's thinking. That is, the questions were leading, sometimes even to the point that the wording of the question provided the steps needed to complete the problem correctly. In addition, some of the pre-service teachers abandoned questioning altogether when a student answered a question incorrectly. Instead of questioning, the pre-service teachers began to instruct the student on how to correctly solve the problem, thus overlooking the purpose of the interview.

Pre-service teachers in the third category, probing and follow-up questions, demonstrated an ability to ask questions that focused on the students' thinking. This type of questioning is critical in the classroom in that it provides the teacher with a way to assess students' understanding. However, Moyer and Milewicz (2002) noted that not all probing and follow-up questions were the same, and that there were inconsistencies as to when this technique was applied. For example, some of the pre-service teachers only probed when students provided an incorrect response. This is problematic in that this style assumes that a correct response means the student understood the concept. Some pre-service teachers, however, did follow up on all answers. Yet even among those that did, some of the follow up questions were generic and did not then provoke a sound mathematical response. Others, however, constructed appropriate follow up questions that built on the student's particular response to a particular problem.

Even though the pre-service teachers in Moyer and Milewicz's (2002) study were not teaching a lesson, the need to construct an effective question based on a student's solution is a skill that will be needed when the pre-service teachers are teaching a lesson. Some of the situations the pre-service teachers encountered during the interview (i.e., unexpected responses, rapid pace) will be similar to those they will encounter when enacting full lessons in the classroom. The study, then, does provide valuable information regarding the process of starting to learn to question. However, additional research is needed that would continue to inform the mathematics teacher education community about the questions pre-service teachers ask in instructional settings and how the work in pre-service teacher courses supports pre-service teachers in developing effective questioning techniques.

2.3 USING REFORM ORIENTED CURRICULA

As stated earlier, the types of tasks in which students engage impacts the mathematics students learn. If students only work on low-level tasks, the learning that occurs is procedural in nature; whereas students who solve cognitively demanding tasks develop a conceptual understanding (Stein, Grover, & Henningsen, 1996; Stein & Lane, 1996). Various studies (e.g., Huntley et al, 2000; Riordan & Noyce, 2001; Senk & Thompson, 2003a; Schoen & Hirsch, 2003; Thompson & Senk, 2001) indicate that students who are engaged in ROC often outperform students who experience more traditional curricular on problem-solving tasks that require a more conceptual understanding of the mathematics. The typical tasks in ROC focus students' thinking on understanding concepts rather than memorizing procedures.

The next sections examine more closely four studies of teachers using ROC and the factors that influence the use of the curriculum. Each provides insight into the current study. First, each study is explored individually, then a discussion of what can be gained from the examining similarities and differences across the studies is presented.

2.3.1 Clarke's study

Clarke (1997) studied two sixth grade teachers, Anne Bartlett and Tim Martin, as they taught a pilot unit from the ROC *Mathematics in Context* (MIC) for the first time. Both teachers had taught sixth grade at the school for approximately 20 years and were currently involved in a six-week professional development program. As part of the professional development, the teachers taught a six week unit from MIC. This unit, which focused on measurement concepts, was comprised of high-level tasks.

One particular finding related to the use of the tasks is that the teachers initially planned to use the tasks as they appeared in the curriculum. However, as the unit progressed the teachers became more comfortable with using their own knowledge of students as a guidepost to modify the tasks. Clarke (1997) noted that the modifications tended to either maintain or increase the cognitive demands of the task. He noted only one instance in which the teacher lowered the demand of a fraction task so that the task was in her personal "pedagogical or mathematical 'comfort zone'" (p.289).

2.3.2 Remillard's study

Remillard's (1999) study focuses on two fourth grade teachers, Catherine and Jackie, in the same working class Midwest elementary school district. Both teachers "had grown up locally, had received their professional preparation from the same university, and were veteran teachers of almost 30 years" (p.320). There were, however, differences between the two, both in philosophies of teaching and learning as well as in professional development opportunities.

Catherine was a rather traditional teacher. In her classroom, she focused on students' mastery of the basic facts and operations. She had few opportunities to participate in professional development, so her knowledge of the reform was from sources such as textbooks and conversations with her colleagues. She wanted to incorporate problem solving in her classroom, but not at the expense of computational mastery. When first exposed to the ideas of the NCTM Standards, she latched onto the "problem of the day" approach. When she eventually began to use the reform-oriented text, she used it for typical suggestions, such as topics to cover and problems to assign. She did not, however, apply other ideas such as the use of manipulatives or group discussions.

In contrast to Catherine, Jackie was more reform-minded even before being introduced to a reform-oriented text. Jackie taught in a school that encouraged and supported teacher growth. She was already making changes similar to those suggested in the reform text in her classroom. She wanted her students to focus on making sense of the mathematics and communicating their thinking and reasoning.

Remillard (1999) distinguishes between two ways of using a text: appropriating and inventing. Appropriation involves taking or using the tasks as they appear in the curriculum. Invention involves some form of adapting or modifying the tasks from the text. Remillard found that Catherine and Jackie used the texts differently. Catherine appropriated tasks from the text. She "trusted the text to provide tasks that embodied [reform-related topics]" (p.323). She would set-up and use the tasks as they appeared in the text, even when she did not quite understand the purpose of the task or agree with the intent. However, she often lowered the demand of the task during enactment by focusing the students on producing the correct answer. Jackie invented her own tasks. She used the text as a means of determining what Van de Walle (2001) refers to as the "big idea" of the lesson or set of lessons. She would then design her lessons around those ideas, often designing her own tasks.

2.3.3 Lloyd's study

Lloyd (1999) studied two high school teachers who chose to implement the reform-oriented curriculum Core-Plus Mathematics Project (CPMP). Mr. Allen, a 14-year veteran teacher, was a traditional teacher for the majority of his career. During the 1994-95 school year, he volunteered to pilot the CPMP materials for the school. Ms. Fay joined the high school math department in the fall of 1996 because of her interest in teaching CPMP. She had taught for ten years, but prior to accepting a position at the high school, she worked for the state government. This position provided her with the opportunity to visit various classrooms using reform-oriented curriculum.

Upon using the CPMP materials, Mr. Allen quickly distinguished them from the traditional curricula in that the CPMP problems "engaged students in sense making activities" (Lloyd, 1999, p.232). He stated that the students developed a better understanding of the material using CPMP. He did, however, have concerns about the open-endedness of the tasks. While he made no changes to the printed tasks in CPMP, he often supplemented the curriculum with review problems for the students to complete at the end of the investigation. He felt more "tied to" the curriculum than he had with the traditional curriculum, stating, "*They* [CPMP] are putting together the real-world application that they want you to use so you are tied to that. It is hard to get away from it" (p.236). Mr. Allen sometimes reduced the demands of the task by providing oral directions rather than allowing the students to fully explore the task as intended.

Ms. Fay viewed the curriculum differently than Mr. Allen. She felt that the CPMP materials were too structured and led the students to the solution too quickly. Similar to Mr. Allen, Ms. Fay also did not make any changes to the written tasks. However, she often presented various solution strategies and would pose questions that she felt pushed students to think beyond the ideas of the written task. Interestingly, though, the solutions presented were often her own. Lloyd notes that the "thinking" in the lesson occurred mainly during the class discussion; the group work still focused on producing the correct answer.

Like Mr. Allen, Ms. Fay also noted "she felt very constrained" in her ability to supplement the CPMP materials (p.241). She gave three reasons though for remaining very close to the curriculum. First, she lacked experience with the curriculum. This was her first time using the CPMP materials, so she was not comfortable making adjustments for fear of eliminating a critical investigation. Second, she was not confident in her own content knowledge. She stated that she had not explored some of these concepts in years. Finally, she felt she did not have the freedom within the department to go at her own pace.

2.3.4 Van Zoest and Bohl's study

Recognizing the reliance teachers often have on textbooks, Van Zoest and Bohl (2002) wanted to examine the role the textbook plays in the field experience, and ultimately, the learning, of pre-service teachers. They studied Gregory, a mentor teacher, and Alice, his intern in high school mathematics, as they both implemented the Core-Plus curriculum.

Gregory had 31 years of teaching experience and had recently made a commitment to teach in a way that was consistent with the NCTM (2000) standards. Gregory's personal commitment led him to use the Core-Plus curriculum. During the year in which Alice interned, Gregory was using the first course in Core-Plus for only the second time, and it was the first time he was using the second course. Gregory wanted to implement the curriculum in a way that would maintain the cognitive demands of the tasks in the text.

Alice had always received high marks in mathematics, but during her undergraduate work she realized that her knowledge was purely procedural and that she lacked a solid conceptual understanding. As a result, she decided that she would work to ensure that when she had her own classroom her students would understand the concepts, not just memorize the procedures. Alice enrolled in a reform-based math methods course that included critical examinations of textbooks.

The authors found that the Gregory and Alice relied heavily on the text while planning, "walking through each of the next day's investigations in order to determine which parts students could answer without guidance, which parts might be skipped or glossed over to increase the pace of student progress, and how to avoid being overly directive while at the same time maintaining student focus on the day's main mathematical concerns" (p.274). Since some of the content, or at least its presentation, was new to both Gregory and Alice, the text often served as a means to strengthen their own content knowledge. Because the text focused heavily on the process standards, Gregory and Alice also found that they needed to redefine their roles as teachers. They needed to shift from being the giver of knowledge to one who facilitated the learning by asking the students questions that pushed the students' thinking. Van Zoest and Bohl (2002) claim that this shift was "definitely supported by, and in some senses determined by, the CPMP textbooks" (p.278).

2.3.5 Looking across the studies: influences on teachers' instructional practices

Each teacher used the text differently and with a different purpose. For example, Catherine viewed the curriculum as a place to gather "good" tasks (Remillard, 1999). This is consistent with Russell's (1996) notion of curriculum as a reference. Jackie also viewed the curriculum as a reference, but not for tasks; rather, she viewed the curriculum as a place to determine the concepts that the students needed to learn. She then developed her own tasks based on those concepts. The teachers from the Clarke (1997) and Van Zoest and Bohl (2002) studies wanted to use the curriculum as it was intended, viewing the curriculum as a guide that might direct the mathematics and learning along a productive path. This is consistent with the view of curriculum as "teacher-proof" (Russell, 1996) in that the teachers expressed an idea that if they could just implement the curriculum as intended, the student learning gains would be high. One might wonder why these differences in how the teachers used the curriculum occurred. That is, what are some of the influences on teachers' instructional practices when they are using ROC? This section discusses possible influences that emerge from the studies discussed above: beliefs, mentor of an intern, coursework/professional development, content knowledge, knowledge of students, and curriculum structure.

2.3.5.1 Beliefs Clarke (1997) noticed a difference between the two teachers in his study regarding their views of mathematics and the way in which they implemented the MIC unit. For Martin, his need to tell students how to solve a problem versus the philosophy of letting students struggle continued throughout the unit. He soon began to see the value of allowing students to struggle with cognitively demanding tasks. He mentioned in an interview that he realized that he should make a variety of materials available to students as they solve the tasks, not just the materials he thinks are the "best" to use on the task. Martin's beliefs about teaching and learning began to change as a result of the MIC unit, and accordingly, the change in beliefs began to impact how he taught the unit. In contrast, Bartlett seemed unable to move away from a traditional view and understanding of mathematics towards a more integrated view that involves big ideas and reflection on solutions. She tended to emphasize "individual techniques or tasks in a lesson, with few attempts to get at any of the connected, big ideas that the teachers' guide emphasized" (p.292).

In Remillard's (1999) study, Catherine and Jackie each held different views about the teaching and learning of mathematics. Catherine believed students learned by being told; she also expected a similar relationship between herself and the text. She anticipated that the reform text would tell her how to teach in a new way. This belief impacted her appropriation of tasks. She wanted a step-by-step format, and was often frustrated when the text was not as clear as she wanted it to be. She felt that it did not meet her needs and expectations. Jackie, on the other hand, believed math to be a "body of related ideas and relationships that needed to be understood" (p.321). She believed that learning occurred in students struggling with complex tasks, developing methods that made sense to the individual student and communicating about the mathematics and methods. These beliefs influenced her invention and the use of the text as a resource for the big ideas, not a set of prescribed tasks.

Both teachers in Lloyd's (1999) study volunteered to implement the CPMP curriculum. Although Mr. Allen's prior teaching was more traditional, he stated he valued the ideals of CPMP. He felt that the students would learn more if they were pushed to think more critically about the mathematics than traditional texts had required. He viewed CPMP as a vehicle to help him accomplish this goal. He valued the more investigative approach that allowed students to produce multiple solution methods. Ms. Fay was looking for a curriculum that more closely aligned with her beliefs. She stated that prior to using CPMP, she had "'always used groups and …always had a project focus'" (p.231). She felt the philosophy of CPMP closely aligned with her own goals and ideas regarding the "best" approach towards engaging students in the learning of mathematics.

2.3.5.2 Coursework/Professional Development Both teachers in Clarke's (1997) study were involved in a professional development program while they implemented the MIC unit. The program consisted of four meetings. The first two meetings occurred prior to the start of the unit and focused on the philosophy of MIC as well as involving the teachers in solving and discussing tasks from the unit. The third meeting occurred halfway through the unit and served as a means of discussing methods of assessment. The purpose of the final meeting, which occurred near the end of the unit, was to debrief the experience. The teachers also had the support of a project staff member as they taught the unit. These professional development experiences provided the teachers with a degree of familiarity with the goals, both mathematical and pedagogical, of the unit as well as the actual tasks in unit prior to teaching. Martin indicated that the awareness of the underlying principles of the project allowed him to more freely attempt the curriculum as it was intended.

The availability of professional development was a critical difference between Catherine and Jackie in Remillard's (1999) study. Jackie had many more opportunities for professional development that supported the reform than did Catherine; however, Catherine's involvement in Remillard's study did begin to influence her teaching. So while Jackie may have had a head start, Catherine began to change as she participated in development opportunities. She states that her interactions with Remillard during the study prompted her to "look at more of the suggestions in the book" (p.327).

2.3.5.3 Mentor of an intern Van Zoest & Bohl's (2002) study demonstrates a clear impact of the mentor teacher on a pre-service teacher's use of a curriculum. The willingness, commitment, and support of Gregory impacted Alice's use of and interaction with the Core-Plus materials. Through their joint planning sessions, Alice grappled with both mathematical and pedagogical decisions regarding how to use the materials in the text in a way to best serve the students' learning.

2.3.5.4 Content knowledge Previous research indicates that a teacher's content knowledge impacts the enactment of lessons (Fennema & Franke, 1992). Clarke (1997), Remillard (1999) and Van Zoest and Bohl's (2002) studies also point to the impact content knowledge has as a teacher interacts with the text and begins to plan a lesson. Clarke (1997) noted that as the MIC unit progressed, some of the tasks "were moving into 'mathematical territory' that seemed somewhat uncomfortable for Bartlett" (p.292). For example, Bartlett often questioned if the correct operation was being used to convert between units of measurement. This became more problematic as she attempted to spontaneously pose an additional task. Her lack of content knowledge also impacted her ability to fully capitalize on one of the key ideas of the unit: "the strengths and weaknesses of a variety of different models for approximating body-surface area" (p.292). Instead of discussing and analyzing the strengths and weaknesses of various methods, as Martin did successfully, Bartlett presented each method as an independent way to solve the problem.

Catherine and Jackie had different understandings of what mathematics is and what it means to do mathematics. As a result they each related to or "read" the text differently. For example, Jackie had a conceptual understanding of the mathematical ideas she taught. This led her to invent her tasks, using the text mainly as a means to identify the key concepts that should be taught.

Mr. Allen's notion of function and the link to his teaching was explicitly discussed in Lloyd and Wilson (1998). Prior to teaching a unit from CPMP on functions, Mr. Allen participated in a series of interviews and function-sorts. During the function sort, he separated a variety of cards into piles that he determined. Through the card sort and interviews, Lloyd and Wilson determined that Mr. Allen preferred a rather traditional view of functions. He selected a correspondence definition of function rather than a covariation definition as his formal definition of a function. However, he viewed highly the covariation-centered concept and graphical representations of functions. The authors point to this belief and knowledge of functions as a critical factor in his ability to use and feel comfortable with the CPMP curriculum, noting that his "conceptions contributed to an instructional practice that encouraged students to utilize a variety of representations and connections among them to investigate real-world occurrences of different families of functions" (p.261). His views of functions also led him to supplement the

CPMP activities. While CPMP moves gradually towards explicitly using equations, Mr. Allen created worksheets that focused students towards the use of recursive rules at the start of the unit. In the Van Zoest & Bohl (2002) study, while Alice and Gregory's content knowledge allowed each of them to engage with the tasks during the planning sessions, the presentation and level of understanding required for many of the ideas of the Core-Plus curriculum were new. As a result Alice and Gregory actually used the text as a means to strengthen their own content knowledge.

2.3.5.5 Knowledge of students The teachers in Clarke's (1997) study both stated that they intended to use the tasks in the MIC unit as they appeared; however, shortly into the unit, both drew on their knowledge of the students as they began to make modifications to the tasks. Both teachers stated that the changes were based on the class as a whole rather than on knowledge of an individual student.

Remillard (1999) also found that the teacher's knowledge of students impacted how they used the curriculum. Jackie adjusted the tasks used in the classroom as she developed a better understanding of how her students thought about and understood the mathematics. For example, after Jackie noticed that her students were not approaching a combination problem in a productive way, she posed a new question (thus adapting the task) that focused the students on what Jackie considered a more systematic approach. Remillard notes, "when Jackie felt pulled between following the text and following students, she always followed students" (p.335).

2.3.5.6 Restrictions from the department/district Lloyd (1999) stated that Ms. Fay felt constrained in how she used the curriculum in part because of a "sense of obligation to colleagues" (p.242). Ms. Fay wanted the freedom to do more projects with the students and allow the understanding of the students to determine the pace. However, she felt that the math department in her school wanted everyone to be on the pace, to be uniform in their use of the curriculum. This struggle led Ms. Fay to feel that she could not fully control the curriculum.

2.3.5.7 Curriculum structure One critical factor in the teacher-text relationship is the structure of the text (ie., a traditional text versus a reform-oriented text). Remillard's (1999) study showed that Catherine's decisions about the lesson were directly steered by the textbook. She used the curriculum as a means of establishing the "topic's mathematical content, sequence, and pace" (p.335). Interestingly, as Catherine interacted more with the reform-text, she began to make more significant changes to her planning and teaching. She allowed more time for exploring rather than skipping the tasks that took too much time, as she did in the beginning of the year.

As stated earlier, Mr. Allen did not make any changes to the printed tasks in the CPMP curriculum, despite the fact that he was originally concerned about the open-endedness of the tasks. He felt that unlike traditional curriculum, the CPMP curriculum did not allow the teacher to "personalize" the tasks (Lloyd, 1999, p.236).

In Van Zoest and Bohl's (2002) study, Alice and Gregory's determination to attempt to use the tasks in the curruciulum as they were written was a strong factor in how they envisioned their lesson plan playing out in the classroom. It begs the question: would Alice and Gregory have made the same pedagogical decisions if they were using a traditional text?

2.4 PRE-SERVICE TEACHER EDUCATION

Learning how to teach mathematics in a way that promotes and supports students' mathematical thinking and reasoning is not a trivial task (Brown & Borko, 1992). Various studies have examined the process of becoming a mathematics teacher and factors that both support and inhibit developing instructional practices that align with the reform. These factors include individual aspects such as one's mathematical content knowledge and beliefs as well as programmatic aspects such as methods courses and field experiences. This section describes pertinent research from three projects- Cognitively Guided Instruction, Project START, and Learning to Teach Mathematics- as they were implemented with pre-service teachers.

2.4.1 Cognitively Guided Instruction

Cognitively Guided Instruction, or CGI, is an approach that focuses on helping elementary teachers use knowledge of students' mathematical thinking gained from research as well as the teacher's questioning in the classroom to make informed instructional decisions (Carpenter & Fennema, 1991). In general, a student in a CGI classroom spends time solving problems in a way that is meaningful to that student and sharing, questioning, and discussing solutions with other students and the teacher until the student understands the solutions to the problem. The teacher facilitates this process by listening to the student, asking questions to clarify the student's thinking, and making instructional decisions that are based on the mathematical needs of the student (Fennema et al, 1996).

Originally, CGI was geared towards practicing teachers; however, Vacc and Bright (1999) examined the impact of the CGI principles on pre-service elementary teachers' beliefs and instructional practices when the principles were integrated into the math methods courses. During the methods course, the students were introduced to "problem types for the basic operations and children's solution methods… and knowledge of children's geometrical thinking" (p.94-95). Discussions during the CGI sections of the course (5 classes) centered on making instructional decisions based on knowledge of students' thinking.

Vacc and Bright's (1999) study focused specifically on two of the 34 pre-service teachers in the course, Helen and Andrea, because of the similarities between their field-experience placements. Both were student teaching in third grade classrooms in the same school. One difference, however, was that Helen's mentor teacher had significant experience with CGI, whereas Andrea's mentor had only attended "a 2-hour 'awareness' workshop about CGI" (p.93).

During the course of the study, Helen and Andrea each completed the CGI Belief Scale at the beginning of the program, beginning of the methods course, beginning of student teaching, and the end of student teaching. While both Helen and Andrea's scores increased from their initial score at the beginning of the program (thus indicating a stronger alignment with the principles of CGI over time), the factors that influenced the changes differed for each individual. The methods course seemed to positively impact both participants; however, Helen's score continued to increase through her student teaching experience whereas Andrea's scores leveled off after the methods course. Further examination of their instructional practices also indicates differences in the implementation of CGI principles. Helen's classroom had some qualities of a CGI classroom, in that students consistently solved and discussed problems; however, Helen didn't effectively use her knowledge of students' thinking to make instructional decisions. When Andrea's students engaged in problems solving, they, too, would share and discuss solutions; but these types of lessons only occurred sporadically.

One possible factor Vacc and Bright identify as an influence on Helen and Andrea's CGI Belief Scale score and instructional practices is the knowledge and support of the mentor teacher in using CGI principles. While the both Helen and Andrea agreed at the end of the methods course "that children's mathematical thinking is important and that instruction needs to be based on problem solving", their field experience classrooms did not equally support or cultivate these beliefs further. The lack of coherence between the coursework and the field experience for Andrea may have caused her to question the applicability of her knowledge gained in the methods course.

2.4.2 Project START

Project START focused on elementary pre-service teachers in a one-year master's certification program at the University of Pennsylvania. Ebby (2000) studied how three elementary pre-service teachers in the project "made sense of their own experiences" (p.75) in their math methods course and subsequent teaching experiences in their math classrooms during their field experience. In general, all three teachers shifted away from a traditional model of the teacher as the giver of knowledge towards a more student-centered model of the teacher as the facilitator of student interactions to promote learning. However, each pre-service teacher experienced this shift at different times prompted by different factors.

Julia entered the methods course feeling confident in her ability to do mathematics; however, engaging with challenging tasks soon led Julia to realize that she did not fully grasp the concepts behind the procedures she could quickly and accurately perform. She soon came to realize the power of seeing other's solutions to a problem and communicating about the different methods. As she continued to grow in her own understanding of mathematics in the methods course, she began to see the students in her mentor's classroom have similar experiences. Her mentor used tasks that allowed for multiple solutions and the mentor encouraged students to discuss their thinking, particularly in small groups. The student's experiences in Julia's field placement classroom emulated her own experiences in her methods course. This prompted her to rethink the notion of teaching by telling. Instead, Julia wanted to continue to provide her student with opportunities to communicate about sound mathematics. When Julia began teaching, she "assessed the effectiveness of her lessons based on whether she felt that students had been able to construct meaning" (p.80).

The methods course was also influential for Amy. In fact, the course was more defining for Amy than the field placement. Amy enjoyed seeing and discussing various solutions (both correct and incorrect) to problems in the course. The idea of a problem being solved in more than one way was new to Amy and greatly impacted her teaching. She became fascinated with her students' thinking and soon realized that traditional methods, such as those used by her mentor, did not provide the teacher with adequate knowledge of how students are thinking about and solving problems.

Unlike Julia and Amy, Michelle was not at all confident in or comfortable with her own mathematical knowledge. Her own experiences as a student in mathematics courses were unpleasant. After taking the required number of courses in high school, Michelle avoided additional math courses. Upon entering the methods course, she was very apprehensive. As a result, she rarely participated in the methods course. However, she soon realized that the students in her field placement classroom were not experiencing mathematics in the same way she did in elementary school. The students were provided with opportunities to problem solve and communicate their understanding with other students. Through her observations and own teaching, Michele noticed that the students seemed confident in their own abilities to do mathematics and talk about their thinking and reasoning. Her experiences in her field placement broadened her own view of mathematics as well as her view of what students know and are able to do mathematically. This caused her to reassess her role as a teacher, recognizing that she *was* actually capable of doing mathematics, as were her students. As a result, “she began to envision a more active role for the student[s]” in her classroom (p.90).

2.4.3 Learning to Teach Mathematics

Learning to Teach Mathematics (Borko et al, 1992; Eisenhart et al, 1993) examined the process of becoming a middle school teacher by tracking a small group of pre-service teachers from their final year of the teacher education program through their first year of teaching. The researchers sought to understand the “novice teachers’ knowledge, beliefs, thinking, and actions related to the teaching of mathematics” along a variety of domains, including mathematical content, pedagogy, and curriculum (Borko et al, 1992, p.199). One particular facet of the program was the focus on the relationship between the university coursework and field placement experience.

The eight participants in the study were a subset of a cohort of 38 pre-service teachers in a K-8 teacher education program. Each of the participants had a concentration in mathematics that required approximately 20 semester hours of coursework. Both Borko et al (1992) and Eisenhart el al (1993) focus primarily on one pre-service teacher- Ms. Daniels- as she experiences mathematics as a learner in her methods course and then attempts to enact conceptually based lessons in her field placement classrooms.

Ms. Daniels was confident in both her own procedural knowledge and her ability to directly instruct students on how to use various procedures; however, the same was not true for conceptual knowledge. She often struggled during interviews and in her math methods course with problems that were conceptually based. In addition, “she had difficulty articulating how she would teach for conceptual knowledge” even though she viewed conceptual knowledge as a critical component of mathematical understanding (Eisenhart et al, 1993, p.17).

Her uneasiness with conceptual knowledge was evidenced in her teaching. She often began with a purely procedural task or on several occasions lowered the cognitive demands of the lesson by proceduralizing the task or providing memorization aides (Eisenhart et al, 1993). For example, while working with her sixth graders on division of fractions, she began by reviewing the traditional algorithm of “multiply by the reciprocal”. When a student questioned the reasoning behind the procedure, Ms. Daniels attempted to provide a conceptual explanation, it was, however, both teacher-directed and mathematically incorrect (Borko et al, 1992). While she later reflected on the fact that the explanation was lacking, her main focus of the reflection was that she spent too much time with the explanation, a sentiment that was also emphasized by her mentor teacher in his feedback on the lesson (Eisenhart et al, 1993).

In addition to her knowledge base hindering her instructional practices, Ms. Daniels also felt a tension between the ideas espoused in the methods course and her experience in her field placement classroom. In her fourth grade placement, Ms. Daniels stated that she felt a great deal of pressure to “[cover] all the topics in the mathematics curriculum” in order to prepare her students for the end of the year standardized test (Eishenhart et al, 1993, p.19). According to Ms. Daniels, teaching conceptually would take too much time and not permit adequate coverage of the curriculum.

The “tension” between teaching in a procedural manner versus using a conceptually based approach evidenced in Ms. Daniels teaching may have, in fact, mirrored the tension felt by her methods course instructor. Feeling the pressure to be “realistic” about what the pre-service teachers would be able to do in their field placements, he hoped to provide the pre-service teachers with meaningful ways to teach algorithms, such as using manipulatives. He spent the first part of each class lecturing on and demonstrating such methods to the whole class and then used the second part of the class as a time for the pre-service teachers to practice the newly learned skill. This method, however, may have backfired in that “many of the [pre-service] teachers perceived the demonstrations and practice sessions as routines to memorize, rather than explanations to understand” (Eisenhart et al, 1993, p.27). They were interpreting the lectures as a step-by-step procedure to follow in their own classrooms.

However, even with the instructor’s efforts to alleviate the tension between the ideals of the coursework and the reality of the field placements, the pre-service teachers still expressed a concern towards the end of the course that what they were experiencing in the coursework did not, in fact, help them teach. At a larger level, the school districts and schools may actually be critical factors that contributed to the pre-service teachers’ apprehension. At the district level, informal communication and in-service activities did emphasize that students should develop a conceptual understanding and meaning behind the mathematical procedures; however, the adhered to objectives and tests of accountability were both very procedural in nature. In the same respect, the local schools also presented conflicting messages about what effective mathematics instruction looks like in the classroom. As a result, Ms. Daniels (as well as the other pre-service teachers) did not have strong models of conceptually based teaching in their field placements (Eisenhart et al, 1993).

2.4.4 Frykholm’s study

Frykholm’s (1996) study also found that pre-service teachers feel tension between their coursework and field placements. Over a two year period, he observed 44 pre-service teachers in a secondary (9-12) certification program, which included two math methods courses that focused on the NCTM Standards documents. The first course used the *Curriculum and Evaluation*

Standards (NCTM, 1989) and emphasized modifying traditional curriculum to provide students with additional opportunities to think and reason about mathematics in a meaningful way. The second course utilized the *Professional Standards for Teaching Mathematics* (NCTM, 1991) as a means to explore pedagogical issues such as alternative methods of teaching and assessing students' understanding. During the course of the study, Frykholm was the university supervisor for 41 of the 44 pre-service teachers.

Three key findings arise from Frykholm's study. First, although the pre-service teachers claim that their teaching at least somewhat parallels the ideas of the *Standards*, Frykholm found little evidence to support their claims. Of the 153 lessons he observed, only 15 were coded at "innovative" while 88 were coded as traditional. Of the remaining 50, six were unclassifiable and 44 were labeled as "traditional-plus", meaning that the lesson was primarily traditional, but incorporated some superficial standards-like feature, such as allowing "students to work on the homework problems in a group" (p.675).

The second key finding is that, as in other studies, the pre-service teachers felt a tension between the university and field placement with respect to implementing a student-centered approach to teaching that stresses thinking and reasoning. Again, the ideas explored in the methods courses were often in conflict with the messages from the schools. While approximately 77% of the students felt a good amount or great deal of pressure from the university to "teach like the *Standards* recommend", only 20% felt the same pressure from their mentor teacher (p.672). One dimension that Frykholm's study adds is the inclusion of the university supervisor as a factor on the pre-service teachers' dilemma. He notes that the students often felt the need to let him know that he "would 'not be seeing much of the *Standards* today'" (p.671). However, the influence of the supervisor may have been minimal since only 3 of the pre-service teachers reported that the supervisor was a strong influence on their teaching philosophy.

The final finding is that the pre-service teachers reported that the mentor teacher is the greatest influence on their development as a teacher, both with respect to their instructional practices and underlying teaching philosophies. Very few of the pre-service teachers reported discussing the *Standards* documents with their mentors. This is not surprising, considering that 31 of the pre-service teachers claimed to mirror the instructional practices and philosophies of their mentor to a moderate degree or more.

2.5 SUMMARY

The instructional practices in a classroom can greatly impact student learning. For example, the tasks with which students engage, the representations made available throughout the lesson, and the discourse may all combine to create an opportunity for students to think and reason in complex ways; or, one aspect of this framework may play out in such a way that the students' opportunities to learn are inhibited.

While there is a growing body of research surrounding practicing teacher's use of instructional practices that align with the ideas of the reform, very little is know about pre-service teachers' instructional practices. Much of the current research has focused on what pre-service teachers learn from coursework at universities that inform pre-service teachers about current understandings of "best practices" in teaching mathematics. Again, though, little is actually known about how pre-service teachers, particularly secondary pre-service teachers, make use of the information in their field placements.

This study, then, seeks to describe the instructional practices of two pre-service secondary mathematics teachers as they plan for, enact, and reflect on lessons in their field placement classrooms. In addition, this study seeks describe how aspects of the contexts appear to influence the selection and implementation of tasks, the use of representations, and the questioning used by the pre-service teachers.

3.0 CHAPTER THREE: METHODOLOGY

3.1 INTRODUCTION

The purpose of this study was to describe the instructional practices of two pre-service secondary mathematics teachers during their internship experience. Specifically, the study aimed to examine critical dimensions of instructional practices: the cognitive demands of the tasks as selected and enacted by pre-service teachers, the mathematical representations used as a tool during the lesson, and normative practices of questioning used to prompt mathematical thinking, reflection, and discussion of the students. Additionally, the study aimed to examine and describe the ways in which the contextual settings, particularly curriculum and the mentor, appeared to influence the instructional practices of the pre-service secondary teachers as they planned for and enacted mathematics lessons in their field placements.

This study employed a qualitative case study method (Merriam, 1998) as a means of capturing detail over time in multifaceted and "situated relationships" (Stake, 2004, p.440) in which the behaviors cannot be controlled (Yin, 1994). More specifically, the current study used an embedded multiple-case study design since there were two cases with multiple units of analysis (Yin, 1994). A strength of this case study method was the "ability to deal with a full variety of evidence- documents, artifacts, interviews, and observations" (Yin, 1994, p.8), all of which were critical to the present study. Ethnographic techniques were used during data collection and analysis. The researcher was a passive participant (Spradley, 1980); that is, the researcher observed the participant in different situations during the school day (e.g., during teacher meetings, during lunch time, while teaching classes) and interactions with the participants were limited. The following sections provide further descriptions of the methodology of this study. In particular, the context, participants, data sources, and analysis techniques are described.

3.2 CONTEXT

This investigation focused on two pre-service teachers enrolled in the Master's of Arts in Teaching program (MAT) at a large urban university in the northeast (hereafter referred to as University) during the 2005-2006 school year. In addition to the required coursework for the program, both of the pre-service teachers were also participating in a professional development initiative, **E**nhancing **S**econdary Mathematics Teacher **P**reparation (ESP), with their mentor teachers. This section describes the larger context of the study- the MAT program and the ESP project.

3.2.1 The MAT program

The MAT program is a fifth-year certification program that culminates in a Master's degree in Teaching and Instructional 1 certification in secondary (7-12) mathematics. Acceptance into the program requires a bachelor's degree in mathematics (or equivalent course experience) with a minimum 3.0 QPA. The program consisted of coursework and an internship (ie., field placement). The coursework spanned a 12-month period, beginning the summer prior to the start of the internship and finishing the following summer. In addition to the coursework taken at the university in the late afternoon and early evening, pre-service teachers also completed a full-time internship at a local public school classroom. The coursework and internship components are further described below.

3.2.1.1 Coursework The MAT program focused on providing the pre-service teachers with rich experiences in their coursework that aimed to prepare them to develop lessons that were cognitively demanding, enact student-centered instructional practices, and reflect critically on the enactment of the lessons. To that end, throughout the year the pre-service teachers took seven mathematics education courses: a teaching lab that focused on lesson planning, a methods course focused on algebra teaching and learning, a methods course focused on curriculum, a methods course focused on the appropriate use of technology in the classroom, a methods course focused on the teaching and learning of proportional reasoning, a course designed to support students' creation of a professional portfolio of practice that is focused on reflection, and a research seminar during which individuals completed an action research project. Table 1 outlines the courses taken by semester. Throughout each of these courses, the pre-service teachers engaged in a variety of activities that compelled them to expand their own understanding of mathematics, how children learn mathematics, and how to facilitate a student-centered lesson that focuses on exploring and discussing significant mathematical concepts and ideas.

	Summer	Fall	Spring	Summer
Internship		• Full day in schools	• Full day in schools	• Full day in schools
Methods	• Teaching Lab	• Algebra • Curriculum • Technology		• Proportional Reasoning
Other Courses with Math focus		• Psychology of Learning and Development	• High School Mathematics course (via math department) • Disciplined Inquiry	
Seminars		• Internship seminar	• Internship seminar	• Research seminar • Internship seminar •
General Education Courses	• Education and Society		• Students with Disabilities in Secondary Classrooms	

Table 1. Overview of classes taken by the MAT students

In addition to the mathematics education courses, the pre-service teachers took two courses that provided a focus on mathematics: 1) a course in the mathematics department that focused on the big ideas in high school mathematics and 2) a course in the education department that introduced psychological theories and research that has impacted the teaching of secondary mathematics and science. Additionally, the pre-service teachers participated in an internship seminar once a week during the fall and spring semesters that provided them with an opportunity to discuss issues such as classroom management, parent-teacher conferences, and job searching with their colleagues. Two general education courses completed the course requirements for the pre-service teachers.

The MAT program is grounded in a practice-based approach to teacher education (Smith, 2001). That is, the activities in which the pre-service teachers engaged were set in the everyday work of teaching such as lesson planning and assessment of students' understanding. Authentic artifacts of practice (e.g., tasks, student work, classroom episodes) were used and analyzed through various lenses. This notion of teacher education is different from the traditional view in that "instead of learning theories and applying them later to practice, teachers witness the emergence of theories from the study of practice" (Smith, 2001, p.16).

While engaged in activities such as those described above, the pre-service teachers were introduced to a set of tools and frameworks that formed the core of the mathematics education program. The tools and frameworks (see appendix A) included the Thinking Through a Lesson Protocol (Smith & Bill, 2004; Hughes & Smith, 2004), Math Task Analysis Guide (Stein et al, 2000), Math Task Framework (Stein & Lane, 1996; Stein, Grove, & Henningsen, 1996), Cycle of Teaching, Boaler and Brodie's (2004) categories of questions, and the five representations of a function (Van de Walle, 2004). These tools and frameworks were used in multiple courses as well as in the supervision process (which will be described in section 3.2.1.2) thus promoting consistency across the program and focusing the pre-service teachers on what the mathematics education program identifies as the critical aspects of teaching mathematics.

For example, three of the courses (the teaching lab, algebra methods, and proportional reasoning methods) required that the pre-service teachers complete a Planning, Teaching, and Reflecting (PTR) assignment. The purpose of the PTR was to provide the pre-service teachers with the opportunity to plan a lesson using the Thinking Through a Lesson Protocol. The

Thinking Through a Lesson Protocol is designed to provide support when planning a lesson that revolves around a high-level task. The protocol focuses on anticipating what students will do and how the teacher will respond. The emphasis is on supporting students' thinking and reasoning about key mathematical ideas. In all three courses, the pre-service teachers received feedback on the lesson plans. In two of the courses, , the pre-service teachers then taught the lesson. Since the teaching lab occurred in the summer, the lesson was taught to a small group (4-5 pre-service teachers) of peers. The lesson taught during the algebra course was taught in the internship classroom. The lessons were videotaped as a way to allow the pre-service teachers to reflect on the enactment of the lesson. The final part of the PTR assignment involved writing a paper where the pre-service teacher identified ways in which the students' learning was supported and/or inhibited by the pre-service teacher's actions during the lesson. Also during the algebra methods course, the pre-service teachers completed an assignment that involved the analysis of their questioning. The pre-service teachers each audio taped and transcribed a 10-minute segment of their teaching, coded each question using Boaler and Brodie's (2004) categories, and completed a written reflection of what was learned as a result of the analysis.

As part of the Disciplined Inquiry course in the spring semester, the pre-service teachers created a portfolio of practice that provided evidence of their reflection and growth over the year. The portfolio consisted of five entries. For each entry, the pre-service teachers made claims about their teaching practices (e.g. change over time, use of formative assessment, and use of a theory to guide their teaching). The claims were supported with evidence gathered throughout the year, such as student work, lesson plans, and written observations from the mentor teacher. The tools and frameworks introduced in other courses provided a lens for the pre-service teachers to reflect on their teaching while creating the portfolio. Additionally, the pre-service teachers were encouraged in the research seminar to use the tools and frameworks as a way to identify an area of interest as well as to collect and analyze the data.

3.2.1.2 The Internship The internship portion of the MAT program involves a field placement at a local public school for the duration of that school's academic year. The internship requires a minimum of 20 hours per week in the field placement; however, the time each district requires varies from 20-40 hours per week. The pre-service teacher is aware of each district's requirements prior to placement[4]. The University outlines a "phase-in process" that serves as a guideline for the field placement experience (see appendix B). The pre-service teachers begin the internship by attending the field placement school's teacher in-service days prior to the first day of school for students. The phase-in progresses from the pre-service teacher's role being that of an observer during the first few weeks, to teaching one class preparation during week 5 of the internship, to two class preparations during week 12, to assuming half of the mentor's schedule (including school duties) by week 18. The pre-service teacher is only expected to take on the full schedule for a two week period. While teaching, the pre-service teacher is "expected to prepare written lesson plans for every lesson taught. The format of the lesson plan may depend upon the subject, grade level, and learner population being taught" (University intern handbook, 2006, p. 29). The University has no required format of the lesson plan; however, the handbook states that mentors and supervisors may have specific formats. Additionally, the University recommends that each lesson plan contain certain elements: "(a) objectives tied to [the state] Academic Standards, (b) content coverage, (c) teaching styles, (d)

[4] In the spring prior to the start of the program, the University hosts an orientation for the incoming MAT students (interns). As part of this orientation, the pre-service teachers interview with the school districts who will be accepting interns. Following the interviews, the students indicate the three schools in which they would like to be placed, the school districts state whom they would like to accept as an intern, and then matches are made.

instructional materials, (e) organization and management, and (f) evaluation criteria and procedures" (University intern handbook, 2006, p.29)".

The University has identified 9 goals of the internship experience. These goals are programmatic; that is, they focus on the MAT program at large (which includes elementary and other secondary certification programs) and not just mathematics. The goals of the internship experience are:

1. To provide the intern[5] with an intensive field-based clinical experience that develops the knowledge, skills, and dispositions required for a career in teaching.
2. To introduce the intern to the auxiliary services of the school and community and explain how these services support the total education process.
3. To provide the intern with opportunities to observe and assist experienced master teachers.
4. To provide the intern with experiences in planning instructional activities, designing curriculum materials, practicing appropriate styles of teaching, experimenting with advanced technology, and evaluating learners' progress and achievement.
5. To provide the intern with opportunities to engage in reflective self- analysis of their own teaching performance, as well as to use constructive feedback from others to refine their teaching skills.
6. To involve the intern in the academic and extracurricular activities of the school.
7. To encourage the intern to draw upon theories of instruction and learning covered in graduate theory/methods courses in order to solve practical problems.
8. To sequentially provide the intern with increasingly comprehensive and complex experiences in classroom instruction.
9. To permit the intern to demonstrate pedagogical performance skills that warrant recommendation for a teaching certificate in his/her specialty area (University intern handbook, 2006, p.11).

[5] The University uses the term "intern" to refer to the pre-service teachers who are in the MAT program.

The University views the internship as “a collaborative venture directly involving the intern, the mentor teacher and the university supervisor” (University intern handbook, 2006, p.9). The mentor and supervisor are expected to orient the pre-service teacher to the profession, providing feedback, and supporting the professional growth of the pre-service teacher. A more detailed description of the roles as defined by the University can be found in appendix C. The University suggests that the supervisor should

> visit the cooperating school early in the term, usually once during the first week, and then schedule subsequent visits on a biweekly basis. In some cases, visits will be scheduled more or less frequently depending upon the intern's progress (University intern handbook, 2006, p.31).

3.2.2 Enhancing Secondary Mathematics Teacher Preparation (ESP)

In addition to the coursework and the internship, the pre-service teachers and their mentors were involved in ESP. ESP is an NSF-funded sustained professional development initiative that focuses on “improving the quality of mathematics teacher preparation” (Smith, 2003-2004, p. 39) by creating opportunities for pre-service teachers and their mentors to reflect on and critically analyze both the mathematical content needed for teaching as well as the instructional practices that support students’ learning of quality mathematics. In particular, a primary goal of ESP is to educate “teacher leaders who can nurture and support pre-service teachers during their internship and student teaching experiences” (Smith, 2003-2004, p.39). To that end, in the year prior to having an intern, mentor teachers engage in a series of six professional development sessions during the school year and an intensive one-week session during the summer as a means to begin to refine their own instructional practices. The mentors are introduced to and use the same tools and frameworks that are central to the coursework of the pre-service teachers.

Additionally, the sessions also focus on the roles and practices of mentoring. To that end, the mentors discussed and practiced structuring conversations with the interns as a way to provide feedback based on evidence collected during an observation. Once the internship begins, the mentor and the pre-service teacher together attend five professional development sessions between September and March. These sessions provided opportunities for the mentors and pre-service teachers to engage in joint planning and reflecting on the enactment of specific lessons from their classroom. The focus of the sessions built on the ideas the pre-service teachers were learning about in the university mathematics education courses (i.e., cognitively challenging tasks, questions, etc).

3.3 PARTICIPANTS

This study focused on the instructional practices of two pre-service secondary mathematics teachers, Keith Nichols and Paige Morris. Keith and Paige were selected as participants in this study because the circumstances of their internships were very similar with respect to the schools in which they were placed and the courses taught, yet differed with respect to the curriculum used in the classroom. This provided an interesting backdrop for analyzing the instructional practices and contextual influences on the instructional practices of each pre-service teacher. Table 2 provides an overview of key elements of the internship placements. The details of each internship placement, including the school setting, mentors, and the curriculum, are further delineated below.

	School	Mentor	Supervisor	Curriculum
Keith	Baskerville Middle	Michelle Fermat, Darcy Dunn	Nicole Thomas	Connected Mathematics; Prentice Hall Algebra 1
Paige	New Carroll Middle	Madeline Larose	Derrick Greene	McDougal Littell's Integrated Mathematics 1

Table 2. Summary of key elements of internship placements

3.3.1 The school setting

Baskerville Middle School and New Carroll Middle School are similar along a variety of dimensions. Both districts are predominately middle-class suburban communities who take pride in the achievements of the schools. The schools in each district have been recognized with various awards for academic achievement. Both schools made adequate yearly progress in the 2004-2005 school year in mathematics as determined by the No Child Left Behind Act. On the state assessment, 60% of the 8th graders at Baskerville Middle School scored at the advanced level and 23% at the proficient level. Similarly, 70% of the eighth graders at New Carroll Middle School were at the advanced level with an additional 20% at the proficient level.

During the course of the study, Keith was teaching 6th and 7th grades, as well as algebra to advanced eighth graders at Baskerville Middle School. He had two mentor teachers- Michelle Fermat for his 6th and 7th grade classes, and Darcy Dunn for this 8th grade algebra class. Paige was teaching various sections of Integrated One, which focuses largely on algebraic topics, to eighth grade students at New Carroll Middle School. Madeline Larose served as Paige's mentor teacher. One algebra-focused class for each pre-service teacher (an honors class for Paige and the 8th grade class for Keith) served as the *focus class* for this study

3.3.2 The mentors

Keith's mentor teachers, Darcy Dunn and Michelle Fermat, and Paige's mentor teacher, Madeline Larose, have similarities in their backgrounds. Darcy received a Bachelor's degree in Secondary Mathematics in 1999 from a local college. Both Michelle and Madeline completed their bachelor's degrees at the University. Michelle graduated in 1998 with an Interdisciplinary Studies degree and then completed her teacher certification, earning an MAT in Elementary Education at the University in 1999. Michele recently added certification in middle school mathematics to her credential by taking and passing the PRAXIS. Madeline graduated with her bachelor's in mathematics in 1999, earning her MAT in Secondary Mathematics Education and teaching certification in 2000. The MAT certification program for mathematics at the University had changed considerably since Madeline had graduated. Specifically, the frameworks that are foundational to the current program were not used at the time Michelle and Madeline attended. Darcy, Michelle, and Madeline all interned during their certification programs at schools that are similar to their current schools. Immediately following their certification programs, Darcy, Michelle, and Madeline accepted teaching positions at their current schools. Darcy has taught 8th grade math and algebra for seven years. Michele has taught a variety of courses at the 6th, 7th, and 8th grades during her seven years of teaching. Madeline has primarily taught the Integrated One course for eighth grade, but also taught Integrated Two at the high school for part of the 1999-2000 school year as part of her internship.

Additionally, all three mentors have participated in various professional development opportunities, including attending NCTM national conferences. Of particular importance is the fact that all three participated in the ESP project as a means to prepare for mentoring an intern.

Darcy was a member of the first ESP cohort, beginning in the fall of 2003; Michelle and Madeline were both members of the second cohort, beginning in the fall of 2004.

During their involvement in ESP, both Michelle and Madeline participated in a study that examined both the teachers' ability to analyze the cognitive demands of tasks and the actual tasks used in their classrooms[6] (Boston, 2006). Using a middle-school task sort (Smith et al, 2004) as the pre/post-measure, Boston determined the teacher's ability to correctly identify the cognitive demands of a task and provide an appropriate rationale for the categorization of the task. Both Michelle and Madeline individually made improvements in their ability to identify and justify the cognitive demands of tasks from the pre-test to the post-test. As shown in table 3, Madeline's scores were consistently close to the sample average while Michelle's scores were well above average, thus indicating Michelle was better able to correctly categorize the cognitive demands of tasks.

	Pre-Test Score	Post-Test Score
Michelle	32	37
Madeline	25	28
Sample Average	24.2	28.7

Table 3: Scores on task sort activity (highest possible score = 35)

Boston also examined the cognitive demands of the actual tasks the teachers used for classroom instruction. Each teacher submitted "task packets" at three points during the year-fall, winter, and spring. A task packet included the main instructional task of each day for five consecutive days. The tasks were then scored according to the Mathematics Academic Rigor Rubric of the Instructional Quality Assessment Toolkit (Boston & Wolf, 2004). Tasks scored as a 3 or 4 indicated that the task, as written, was high-level, while a task that was scored as a 1 or 2

[6] Since Darcy was not a member of the second cohort, she was not eligible to participate in the study. However, Darcy's instructional practices were highly regarded by faculty and instructors in the mathematics education department at the university.

indicated that the task was considered to be low-level. The data, as shown in table 4, indicated that both Michelle and Madeline use high-level tasks for the main instructional task, with Michelle's data indicating she consistently did and Madeline doing so approximately 70% of the time. Specifically, of Michelle's main instructional tasks, 5 out of 5 were high level; Michelle did not complete a winter or spring task packet. Of Madeline's main instructional tasks, 10 out of 15 tasks were high level. Of particular interest is that as the year progressed, Madeline's use of high-level tasks increased.

	Fall	**Winter**	**Spring**
Michelle	3.2 *(5 out of 5 tasks were High-level)*	(no data)	(no data)
Madeline	2.4 *(2 out of 5 tasks were High-level)*	3.0 *(3 out of 5 tasks were High-level)*	3.7 *(5 out of 5 tasks were High-level)*

Table 4: Average score (highest score = 4) on task packets and number of tasks that were high level

In addition to the classroom mentors, both Keith and Paige also met regularly with their university supervisors. Nicole Thomas served as Keith's supervisor. She is a leading mathematics educator who works with both pre-service and practicing teachers. She is the Principal Investigator of the ESP project. She also taught two of the courses which Keith and Paige took during the school year, one of which occurred prior to data collection, and the other after. Derrick Greene, Paige's supervisor, worked for 33 years as a mathematics teacher at a local school district before becoming involved in supervising pre-service teachers for the university. He is well known and respected in his district, which has a very similar population to that of New Carroll Middle School. He has been supervising for the University for six years.

3.3.3 The curriculum

Baskerville Middle School uses two textbooks. The Connected Mathematics Program (CMP), a reform-oriented NSF funded curriculum, is used in the 6th and 7th grades, and for one unit (linear functions) in the 8th grade algebra. CMP "emphasizes inquiry and discovery of mathematical ideas through the investigation of rich problem situations" (Lappan et al, 1998). In the algebra courses, content is primarily taught from Prentice Hall Algebra 1 textbook (2004). The Prentice Hall book is a traditional text, both in format and in content. For example, each section begins by stating the objectives, a skills review, worked out example problems followed by a few problems for the students to practice and "check understanding". Finally, the exercises at the end of the lesson are divided into three sections: "practice by example", "apply your skills", and "challenge".

The curriculum used at New Carroll is McDougal Littell's Integrated Mathematics 1, the first book in a three-year course that addresses "the same concepts and skills found in an Algebra1/Geometry/Algebra 2 sequence". Integrated 1 focuses primarily on algebraic concepts through the use of problems that are set in a real-world context. Most sections begin with a sample problem that provides a worked out response. This is followed by section titled "talk it over", which is a series of questions aimed to extend students' thinking about the sample problem. The sections end with a series of exercises and problems (usually between 20-30 problems) that provide opportunities for students to practice the skills outlined in the sample problems. While the text has elements of a reform-oriented curriculum (i.e., contextual problems, suggestions for group work, the “talk it over” section), these elements are rather surface-level and fade in comparison to the overall focus of the book- practicing skills. Thus, the text is viewed as a traditional textbook.

3.4 DATA SOURCES

This section describes the data that were collected to explore the two research questions (1. What is the nature of instructional practices used by two pre-service secondary teachers in their field placement classrooms? 2. In what ways do the contexts within which each pre-service teacher works influence their instructional practices?). In order to strengthen the internal validity and reliability, two types of triangulation were used: data triangulation and methodological triangulation (Denzin, 1978). That is, a variety of data (i.e., interviews, lesson plans, curricula, and video tapes of instruction) was collected via different methods (ie., interviews, document analysis, observation), thus providing an opportunity to clarify (Stake, 2000) and corroborate the emerging findings (Merriam, 1998). A mapping of data sources and research questions is shown in table 5.

	RQ#1	RQ#2
Videos of instruction in focus class (5 per pre-service teacher)	X	
Copies of curricula from observed lessons in focus class	X	
Copies of lesson plans from observed lessons in focus class (5 per pre-service teacher)	X	
Lesson centered interviews for focus class (5 pre-lesson and 5 post lesson per pre-service teacher)		X
General interviews		
- #1		X
- #2		X
Contextual interviews (interviews with the mentors and other identified informants)		X
Field notes	X	X

Table 5: Data sources mapping to the research questions

3.4.1 Data sources for examining instructional practices

Four main data sources were collected in order to describe the instructional practices of each pre-service teacher: videotapes of classroom instruction, copies of the curricula or other print materials that provide the source and/or support for the videotaped lessons, copies of the pre-service teacher's lesson plans for each videotaped lesson, and field notes. This data was collected from the focus class (as identified above in section 3.3.1) over the course of five consecutive days between late March and early May at the beginning of an instructional unit. The mentor teachers conducted the videotaping, thus allowing the researcher to collect field notes. The mentors were instructed that the focus of the videotaping was on the pre-service teacher, but also to capture the activities of the classroom. The researcher and mentor discussed using wide-angle shots for whole class discussions, close shots for group interactions with the teacher, and zooming in on information written on the board or overhead.

3.4.2 Data sources for examining contextual influences

In order to understand how the contextual settings influenced Keith and Paige's instructional practices, each pre-service teacher participated in two types of interviews at multiple points in time: *general interviews* and *lesson-centered interviews*. In addition, *contextual interviews* were conducted with the mentors and other key players identified in the general interviews. The researcher conducted all the interviews, which were audio taped and then transcribed.

The purpose of the general interviews was two-fold. First, the interviews provided a way for the researcher to gain insight (Merriam, 1998) into how Keith and Paige viewed their respective teaching situations (ie., internship school setting, role of the mentor, coursework, etc.). In addition, the general interviews explored how Keith and Paige made instructional decisions regarding the planning and enactment of a lesson. The general interviews were semi-structured (Fetterman, 1998; Merriam, 1998) and used what Spradley (1980) referred to as descriptive, grand-tour questions (i.e., "Tell me about Baskerville Middle School" or "So I noticed that students did ____. Why did you decide to have students do this during this set of lessons?") and mini-tour or probing questions (i.e., "Could you say more about what you meant by ____?").

Stein, Remillard, and Smith (in press) note that curricular materials may be transformed as a teacher plans for and enacts a lesson in the classroom. Drawing on previous research, the authors identify four main categories that influence transformations: the teacher, the students, the context, and the curriculum. These categories of influence on curricular transformations were used as a lens to design the questions for the general interviews. The categories provided a framework that allowed for the exploration of the ways in which different areas influenced the instructional practices of pre-service teachers. While all the larger categories of the framework were addressed, only sub-categories that directly related to the research questions were used in the creation of the interview questions. For example, questions such as “What does your mentor expect from you?” and “What interactions do you have with other math teachers?” were aimed to examine the support available to and utilized by the pre-service teacher. These interviews occured at two time points: 1) before the videotaping of any lessons that were used in the study; and 2) in May, after the collection and initial analysis of all data (see appendix B for a copy of the general interview protocols.) Each general interview lasted an average of 90 minutes.

The purpose of the initial general interview was to gather both contextual and instructional information. The first part of the interview focused on collecting background information from each pre-service teacher in order to provide the researcher with some insight into how each pre-service teacher made sense of the contextual settings. The questions were aimed at gathering information about the school, the students, and the pre-service teacher’s relationship with the mentor. The second part of the interview focused on the upcoming lessons to be videotaped in the focus class. These questions focused on what would happen in the set of lessons, how decisions about planning were made, and the anticipated roles of both the pre-service teacher and students.

The second general interview focused primarily on gaining insight into each pre-service teacher’s instructional decisions. In preparation for this interview, the researcher watched each of the videotaped lessons and reviewed related documents and data sources (i.e., videos, lesson plans, curricula, previous interviews, field notes) as a means to identify key areas to discuss in the interviews (i.e., interesting decisions, modifications, and instructional moves). Conducting the second general interview shortly after the instructional practices data collection allowed the researcher to ask specific questions that pertained to the videotaped lessons within a reasonable time frame.

Each pre-service teacher also participated in a series of lesson-centered interviews for the focus class (see appendix C). Immediately prior to the start of each lesson, the pre-service teachers were asked to summarize the upcoming lesson, including the goals. This interview provided insight into the pre-service teacher's actual agenda for the lesson (Leinhardt, 1993). After the completion of the lesson, the pre-service teacher was asked to briefly reflect on the lesson. Each lesson-centered interview lasted approximately 2-3 minutes.

Contextual interviews (see appendix D) were conducted throughout the study in order to triangulate the data gathered from the interviews with the pre-service teachers. Previous research (i.e., Ebby, 2000; Frykholm, 1996; Van Zoest & Bohl, 2002) has indicated that the mentor can greatly influence a pre-service teacher's practices. As a result, each of the mentor teachers participated in a semi-structured interview following the data collection in the focus class as well as informal interviews throughout the data collection. Informal interviews are not structured, but rather conversational in nature (Fetterman, 1998); so while the informal interviews were driven by the researcher's observations of the instructional practices and interactions of the pre-service teacher, unlike the semi-structured interviews, there was not be a specified interview protocol to follow. In addition to the mentor teacher, other "key players" (e.g., university supervisor) identified by the pre-service teacher as an influence on instructional practices were interviewed following the second general interview with the pre-service teacher.

A school is a complex setting with many nuances that may not be captured through an interview or on the video of the focus class. In order to gather additional information about the context, the researcher became immersed in the school setting of the pre-service teacher for a one week period by shadowing the pre-service teacher at the school. The researcher was in the "observer-as-participant" role (Angrosino & Mays de Perez, 2000, p. 677) since the primary purpose was to observe, but by the nature of the observations, the researcher also interacted casually with the participants. During this time, field notes were collected as a means to provide a written account of the observations (Merriam, 1998). The purpose of shadowing was to provide insight into the daily routines and interactions of the pre-service teacher. The field notes were comprised of two parts: 1) general notes regarding the setting and interactions of the staff, teachers, and students and 2) notes regarding the actions of the pre-service teacher. For example, a description and map of the school and classroom was included as a means to establish the context. A daily log of the pre-service teacher's actions included information such as time and location of the pre-service teacher throughout the day as well as descriptive data (i.e., conversations, people) surrounding the events. All field notes were gathered in a field journal during the observations, then converted into electronic format immediately following the observation to facilitate coding.

3.5 DATA ANALYSIS

The general analysis scheme for the current study is what Yin (1994) refers to as "relying on theoretical propositions" (p.103) since the data collection and analysis were greatly informed by relevant literature. That is, the research was conducted primarily from an etic, or outsiders, perspective (Fetterman, 1998; Merriam, 1998).

For each pre-service teacher, the data set included audiotapes of interviews, lesson artifacts (i.e., pages from the teacher's edition, the teacher's lesson plans), videotapes of five lessons, and field notes. Prior to analysis, all videos and interviews were transcribed into a format that is compatible with the N6 version of the qualitative data analysis program NUD*IST

(Non-Numerical Unstructured Data: Indexing, Searching, and Theorizing). N6 is a "toolkit" that provides a framework for organizing and systematically coding data using indexed categories for researchers who are examining qualitative data (Gahan & Hannibal, 1998). Since the video transcript served as a tool to supplement viewing the video, only the audio portion of the videos were transcribed; that is, movements and time stamps were not included on the transcript. The teacher was identified, and each new student speaker was simply identified as "student". Pseudonyms were assigned to ensure anonymity. This section outlines the method of analysis for the data sources with respect to each research question.

3.5.1 Instructional practices

The first research question investigates the nature of instructional practices used by each pre-service teacher in the field placement classroom. In order to create individual portraits for Keith and Paige, each videotaped lesson was analyzed with respect to the cognitive demands of the tasks, the representations used by the teacher and/or student, and questions asked. This facilitated comparisons within each pre-service teacher's instructional practices. In addition, the coding allowed for a variety of comparisons between pre-service teachers regarding the tasks, tools, and norms of the classrooms. One video of each pre-service teacher's classroom instruction was independently coded for the critical dimensions of instructional practices as described in the following sections by both the researcher and a trained coder in order to ensure inter-rater reliability. The coder received approximately two hours of training from the researcher surrounding the coding scheme for each dimension of instructional practice. The reliability (stated in percent agreements) for the cognitive demands of the task was 100%, 90%

for the representations, and 82% for the questions. Disagreements regarding the questions were resolved through consensus coding and each question was assigned a single code.

3.5.1.1 Tasks The Math Task Framework (Stein, Grover, & Henningsen, 1996) was used as a guide for analyzing the cognitive demands of the tasks as they progress from the published curriculum to the enactment of the tasks in the classroom. Prior research indicates that the thinking required of the students may change as the task progresses from the written form to the lesson plan (Wagner, 2003), and from the set-up through the enactment in the classroom (Henningsen and Stein, 1997). Therefore, the cognitive demands of all tasks were analyzed at four particular times (as shown in figure 3): 1) in the published curriculum 2) in the lesson plan, 3) as set-up in the classroom, and 4) as enacted in the classroom. The Academic Rigor Rubrics of the Instructional Quality Assessment tool developed by Boston and Wolf (2004) (see appendix E) was used to categorize the demands of the task at each of the four points described above, thus allowing for the assignment of a code that corresponds to the level of the task at each point of analysis. These rubrics draw heavily on the Math Task Analysis Guide (Stein et al, 2000) as a means to determine the type of thinking a task has the potential to elicit as well as the type of thinking implemented by the students in the classroom while engaging with the task. For example, a score of one or two represents a low-level of cognitive demand, while a score of a three or four represents a high-level of cognitive demand. The distinction between the scores at each level focuses on the explicitness of evidence of the potential or observed thinking and reasoning by the students. For example, a task is coded as a four during the implementation if there is clear data that indicates students were thinking and reasoning in complex ways; a task is coded as a three if the task has the potential for such thinking and reasoning, but there is not clear evidence of the students' reasoning and understanding, the task is too easy or too hard for the particular group of students, the students did not make generalizations, or there is no explicit evidence that students made connections between various strategies or representations (see appendix E for the full description of each category).

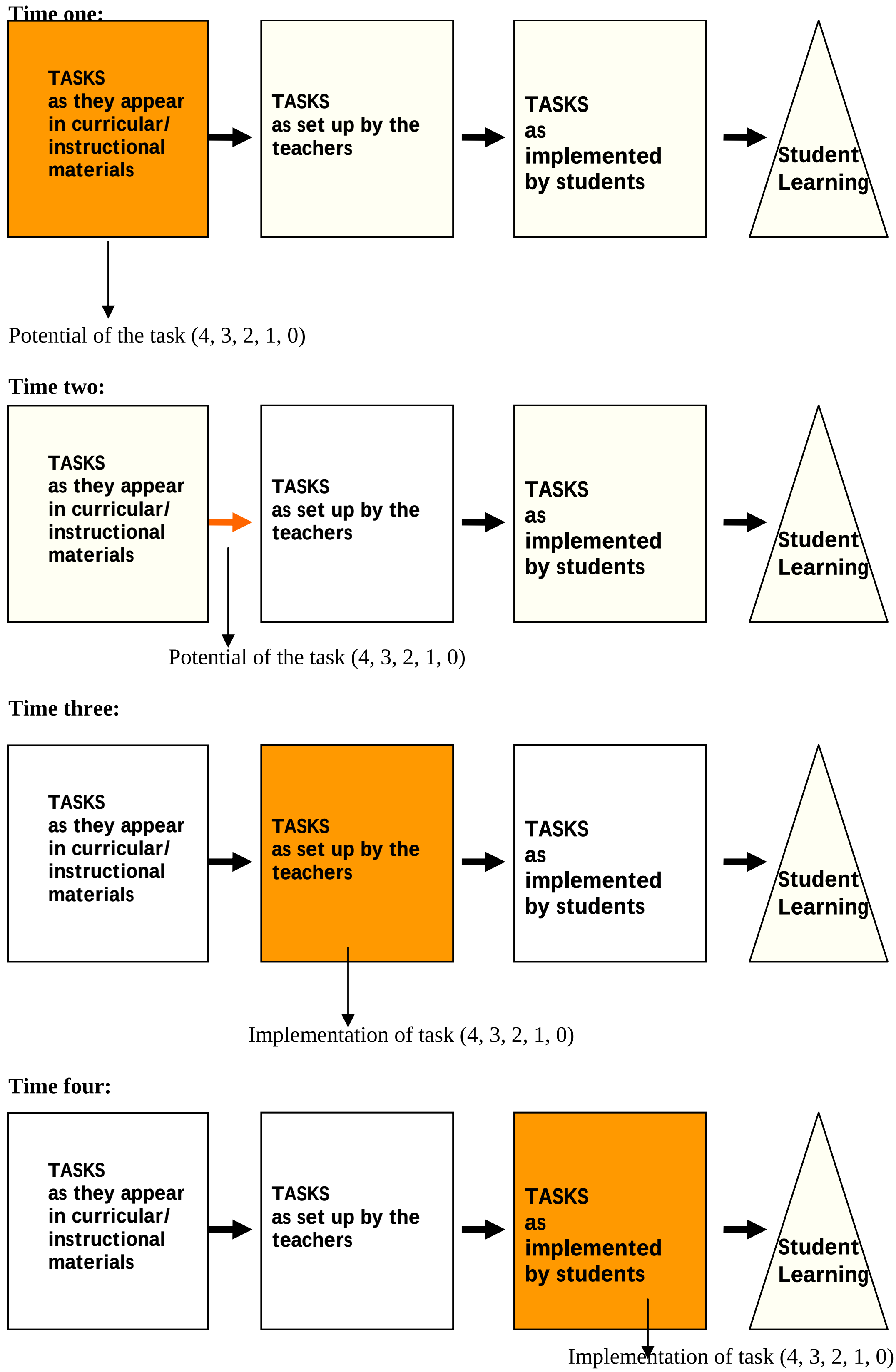


Figure 3. Four points of analysis of cognitive demands of the task

Research indicates that actions by both the student and teacher in a classroom can impact the cognitive demands of the task during the set-up or enactment of a task (Henningsen & Stein, 1997). For the present study, if the cognitive demands of a task declined during the set-up or the enactment, the videotaped lesson was further analyzed for factors associated with the decline of cognitive demands as outlined by Henningsen and Stein (1997). In addition, lessons in which the tasks sustained a high level of cognitive demand from set-up through enactment were coded for factors associated with the maintenance of cognitive demands (Henningsen and Stein, 1997) (see Appendix F).

In addition to analyzing the cognitive demands of tasks, the source of the task was coded as appropriated from the curriculum, adapted, or invented. *Appropriation* (Remillard, 1999) involves using a task exactly as it appeared in the curriculum. A task was coded as *adapted* when changes were made to the original task. Specifically, the task will be coded as *adapted-demands maintained* (Smith, 1999), *adapted-demands increased, or adapted-demands decreased.* If the planned task was similar to the task in the published curriculum, but slight changes were made and these changes do not change the overall intended ideas of the publisher, the task was coded as adapted-demands maintained. For example, this could involve changing the numbers in a problem. If the task was changed in such a way that the cognitive demands compared to the original task changed, the task was coded as *adapted-increased demands* or *adapted-decreased demands*. For example, adapted-increased demands involved modifying directions to a procedural task to encourage students to use multiple representations as a means of developing a conceptual understanding. In contrast, adapted-decreased demands could involve adding directions to a conceptually based task that focused the students only on the procedural aspects of the task. Tasks were coded as *invented* (Remillard, 1999; Smith, 1999) when the pre-service teacher did not use a task from the curriculum, but instead created a new task on their own or utilized resources outside of the published curriculum. Similar to adapted tasks, there are three levels of invention when the planned task is compared to the original task in the curricular materials: maintained demands, increased demands, and decreased demands.

In summary, each lesson was coded for the cognitive demands of the task in the curriculum, the lesson plan, the set-up, and the enactment. Factors that influenced the maintenance or decline of a high-level task were identified. Finally, the source of the planned task was described. This analysis also allowed for comparisons between the pre-service teachers.

3.5.1.2 Tools Transcripts of the classroom videos were coded for the tools available to the students while engaging with a task. The transcripts were divided into *conversations*, or exchanges between teachers and/or students about a particular problem or representation. Representations are a critical tool in supporting mathematical understanding in general (Hiebert et al, 1997; Lesh, Landau, & Hamilton, 1983; Lesh, Post, & Behr, 1987; Pape & Tchoshanov, 2001), and are of particular importance in developing an understanding of functions. Therefore, each lesson was coded for the use of representations of functions along two dimensions: availability and connections. First, the lessons were analyzed for use of the 5 representations of a function as described in Van de Walle (2004). As noted in figure four, these representations include 1) real-world contexts, 2) graphs, 3) equations, 4) tables, and 5) language. The pre-service teachers had the opportunity to explore these representations in the fall methods class, algebra teaching and learning, and were introduced to the same tool used for coding in this study.

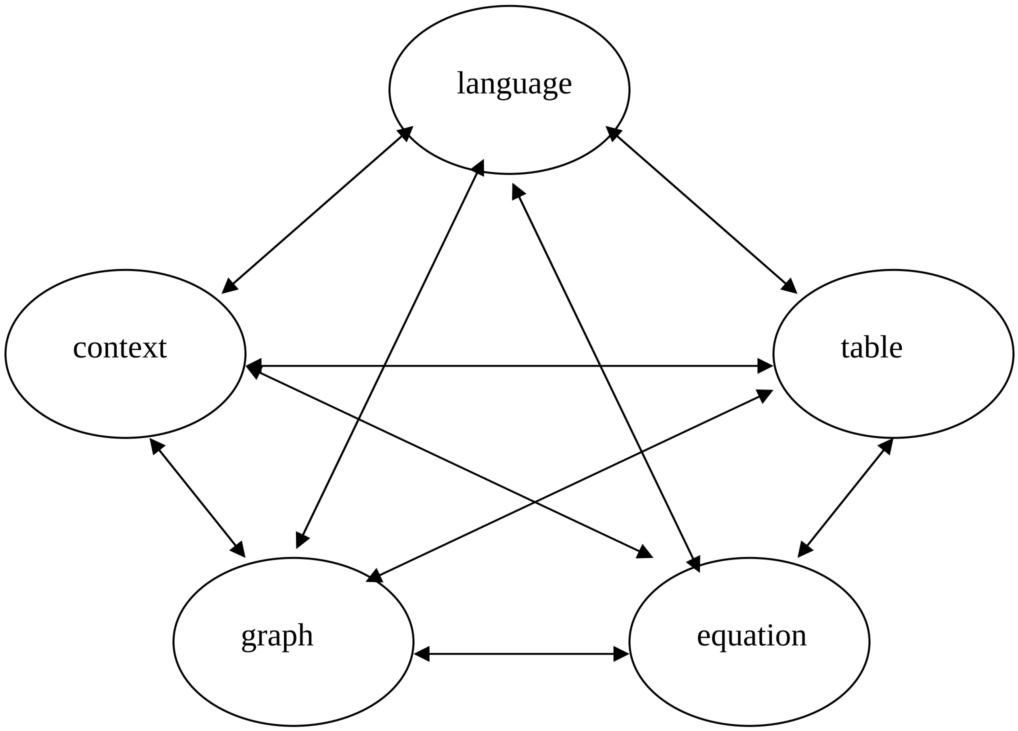


Figure 4. Five representations of a function (Van de Walle, 2004, p.440)

While using a representation is a component of mathematical understanding, a critical aspect of understanding conceptually is "seeing" the connections or relationships between and among the various representations of a mathematical concept or idea (Lesh, Landau, & Hamilton, 1983; Lesh, Post, & Behr, 1987; Pape & Tchoshanov, 2001). As a result, each lesson transcript was coded for connections between and among the representations, as well as who made the connection (i.e., the teacher or the student). This is important since one of the driving forces of the reform is a classroom that is student-centered; that is, the students are grappling with the mathematical concepts rather than the teacher telling the students the key ideas. For example, during a class discussion in Mr. Entigar's[7] class, a student presented the equation y=2x+4 as the equation that modeled the cost of posters. Mr. Entigar then asked: "That two times the x, there? What was it in the problem that kind of gave that away for you?" (Entigar, 2004, Lesson 3, segment 106-107). In doing so, he is asking the student to make a connection between the equation and the context of the problem. The students' response made public the connection between the two representations, thus allowing all students access to this connection. Later in that same class, Mr. Entigar worked with a small group and facilitated their connection between the graph and the context of the same problem.

> Mr. Entigar: "So, think back to the problem. What's making that line go up?"
> Student: "The values are increasing….the posters ordered increases…then the cost goes up."
> Mr. Entigar: "Now, as the posters ordered increase, so does the cost, and that's what's making the line go up? (Entigar, 2004, Lesson 3, segment 445-461)

While the teacher's question prompted the connections in both examples, it is the students who actually made the connection.

Following the coding, a description of each representation available, the function of those representations, connections made, and who made the connections were complied for each videotaped lesson. This aided in developing the portrait of each pre-service teacher's instructional practices with respect to what thinking was happening in the classroom and who was doing the thinking.

3.5.1.3 Norms The norms in a classroom involve the stated and perceived roles of both the students and the teacher. One way of capturing the norms of a particular classroom is by examining the questions posed by the teacher. Questions provide the teacher with a vehicle to

[7] Bruce Entigar is an algebra one teacher whose videotaped lessons served as a basis for developing the coding scheme for the current study. The videotaping of his lesson occurred under the auspices of ASTEROID (A Study of Teacher Education: Research on Instructional Design).

guide student thinking (Newton, 2002), promote mathematical communication (Heibert et al, 1997), and facilitate connections between representations. The type of questions asked over time are critical to the thinking and ultimate understanding a student will develop. Newton (2002) states “if you ask for facts, the mind will tend to concern itself with facts, but if you ask for relationships, reasons and causes, then thinking is more likely to be aimed at constructing relationships, reasons and causes” (p.33).

In order to more fully understand the normative practices of the participants in the present study, each videotaped lesson was analyzed for the types of “academic questions” (Hiebert and Wearne, 1993) the teacher asked. An academic question could be in the form of a question or an utterance that served the purpose of a question (Boaler & Brodie, 2004) that revolved around the mathematical ideas of the lesson. However, questions or utterances that were rhetorical “space fillers” (i.e., “ok?”) were not counted as questions. Consider the following example, “In our table so far we have negative numbers and we do need to account for that. Ok?” (Entigar, 2004, lesson 1, segment 274). While the question “ok”, is connected to a statement focused on the mathematics of the lesson, it is not intended to invoke a response from the students; rather, it is a colloquialism used as a space filler in talk.

This study adapted Newton’s (2002) talk framework as a means to analyze the academic questions posed by the teacher. While Newton focuses on talk, this study altered the unit of analysis from conversations to individual questions posed by each pre-service teacher. This is an important shift since questions are one way to provoke students’ thinking, reasoning, and reflecting on and about mathematics. Newton’s framework provides a general way to classify questions while encompassing more specific question types identified by other researchers such as Hiebert and Wearne (1993), Driscoll (1999), and Boaler and Brodie (2004). Each question was coded as tuning, monitoring, or connecting. The categories are further described below.

The first question type is *tuning*. Questions of this type focus the students' attention on the given task by setting the scene for the lesson and "focusing attention on those specific aspects of the topic where [the teacher] will begin" (Netwon, 2002, p.35). This may be accomplished in one of two ways: by establishing the context (Boaler & Brodie, 2004) or linking to prior mathematical knowledge. The number of tuning questions can vary, depending mainly on the students' prior knowledge (Newton, 2002).

Examples of tuning questions that establish the context include a teacher asking about cell phones when the task is to analyze cell phone plans, or polling the class for their favorite candy if the context of the task involves candy. Linking to the context of a task may also occur in a different format that does not directly link to the real-world setting of the task. For example, Mr. Entigar began a class by asking a tuning question aimed at establishing the context of the lesson- naming something that has always been done. He was setting up a task where the students will be formally introduced to the term "slope", although they have informally worked with the concept of slope throughout the past few months. He asked, "Has anyone ever done anything their entire life, or done something for a long period of time, and like they just didn't even know what was called?" and then continued to discuss dances such as the funky chicken (Entigar, 2004, Lesson 1, segment 15-22).

Tuning questions can also draw students' attention to their prior mathematical knowledge that will be necessary or useful for the task at hand. For example, in the beginning of another lesson, Mr. Entigar pointed to the statement on the overhead, "y=3x-5 is a linear equation". He asked, “Do you believe it?” (Entigar, 2004, Lesson 4, segment 33) as a way to activate students’ prior knowledge of linear equations, which was needed for the upcoming task.

The second type of question, *monitoring*, provides the teacher with an opportunity to assess a student’s thinking and understanding. In doing so, the students are again provided with an opportunity to further their own understanding in that “having children express their thoughts probably makes them think more carefully and completely” about the mathematical ideas of the task (Newton, 2002, p.47). The main purpose of a monitoring question, however, is for the teacher to gain insight into the student’s thinking and reasoning rather than to push the students to make connections. Monitoring questions may take many forms, such as asking students to recall basic information (Hiebert & Wearne, 1993), checking for understanding, and asking students to explain their thinking (Driscoll, 1999; Boaler & Brodie, 2004).

Mr. Entigar used a variety of monitoring questions during lesson one. Students were to recall basic information when he asked questions such as, “What if you want to make a very accurate line, how many points did we say to use?” (segment 267) and “What is the proper terms? What are they called?” (segment 295). He checked students’ understanding by asking questions such as “What’s it mean?” (segment 210), “You can’t have negative posters?” (segment 484), and “Where’s the x and the y-axis on your graphs?” (segment 518). Questions such as, “What do you think?” (segment 278), “Could you show [your group] how you got 18?” (segment 395), and “What did you do for this one?” (segment 627) are all geared at having students explain their thinking.

The final type of academic question is *connecting*. The purpose of this type of question is to facilitate the students in making connections to the mathematical idea of the lesson, and/or conceptual connections between various representations (Newton, 2002). Questions of this type provide students with an opportunity to advance their current thinking and understanding of the topic by prompting further reflection, exploration, application, or analysis of mathematical relationships (Hiebert & Wearne, 1993; Driscoll, 1999; Boaler & Brodie, 2004).

Connecting questions may occur at any point in the lesson, and may be directed to an individual student, a group of students, or to the entire class. For example, as Mr. Entigar's students were working in groups, he approached a particular group. In facilitating students' connection between the graph and context of the problem, he asked the group, "What does this y-intercept, this one point, what does it mean?….What does it mean in the problem?" (Entigar, 2004, lesson 1, segments 870, 874). Similarly, Mr. Entigar prompted the class to further analyze the graph in their groups by asking two connecting questions, "What is it that's happening in your graph? Ok? What do you notice?" (Entigar, 2004, lesson 1, segment 730). These questions were prompting the students to determine how information such as the cost per poster and shipping costs were represented on the graph.

In summary, effective lessons involve all three types of questions since each type of question has a different purpose. It is important that students "tune in" to the lesson by relating the task to their own prior experiences, either personal (i.e., relate to the context) or mathematical (i.e., prior knowledge), and tuning questions provide this opportunity. Teachers must also understand what students are thinking and how they are approaching the problem. Monitoring questions provide a chance for students to explain their thinking, thus allowing the teacher to assess that student's understanding. Finally, if true conceptual learning is to occur, students need to be given opportunities to connect mathematical ideas, representations, and strategies for solving problems. This is the purpose of connecting questions. However, Boaler & Brodie (2004) note that questions of this type are least likely to occur in a lesson.

While there is no formula of how many questions of each type is desirable, research suggests that to promote students' learning along a mathematical trajectory, a teacher should ask a variety of questions. After all questions in the current study were coded, counts for each type of question in each lesson were tallied. Percentages of each type of question were computed to allow for easier comparisons. The level of cognitive demand of the lesson was compared to percentages of question types asked as a means to identify any trends in questioning patterns; this comparison was made within each individual pre-service teacher's instructional practices as well as between both pre-service teachers' practices.

3.5.2 Contextual influences on instructional practices

The second research question sought to document ways in which the context supported and influenced the pre-service teachers' instructional practices. The analysis occurred both during and after data collection (Miles & Huberman, 1994). As noted earlier, the primary data sources for this question were the field notes and the interviews (i.e., general, lesson-centered, and contextual). The coding was guided by features that have previously been identified in the literature as influencing various aspects of the critical dimensions of instructional practice such as the curriculum used in the field placement, coursework, and the mentor teacher, and factors that influenced the maintenance of high-level tasks (i.e., Clarke, 1997; Henningsen & Stein, 1997; Lloyd, 1999; Remillard, 1999; Van Zoest & Bohl, 2002). This provided a focus while conducting the interviews and collecting data in the field (Miles & Huberman, 1994; Ryan & Bernard, 2003). In addition, new features and concepts that emerged from the data were identified by reading the transcripts of the interviews, transcripts of the focus classes, and field notes. Miles and Huberman's (1994) three components of data analysis were employed. First, data reduction occurred through the constant review of the data as a way to focus the analysis. Second, the data was then organized by grouping similar examples of concepts as a way to clarify patterns and possible explanations. Finally, these clusters of examples were identified as "themes" (Miles & Huberman, 1994). All data were the coded again with respect to these themes.

The transcripts were coded in 2 chunks related to the time of data collection: 1) the initial general interview, lesson-centered interviews, informal contextual interviews with the mentor and other key players, and the field notes; and 2) the second general interview and contextual interviews with the mentor teacher and other key players. This provided the researcher with an opportunity to both use the information gained in each chunk for future interviews as well as the opportunity to begin to identify consistent contextual influences.

3.6 PRESENTATION OF RESULTS

The current study aimed to create a portrait of the instructional practices of each pre-service teacher. The study also looked to examine the influences on the instructional practices of each pre-service teacher as perceived by that pre-service teacher. In order to create this portrait, the study employed a pattern matching approach (Yin, 1994). A narrative account of each pre-service teacher was compiled by combining the rich, descriptive, qualitative detail with the quantitative counts. Each portrait provided insight into the tasks, tools, and norms that were characteristic of a typical lesson in each pre-service teacher's classroom as well as how aspects of the context impacted the instructional practices. Additionally, issues that emerged during the analysis of the data were described. Artifacts such as lesson plans, videotapes, and interview transcripts were used to provide evidence.

After each pre-service teacher's portrait was compiled, the two portraits were compared for similarities and differences of instructional practices. This analysis allowed the researcher to determine if certain supports and aspects of the context seem to be consistent across field placement sites, or if each pre-service teacher experienced different influences on instructional practices.

4.0 CHAPTER FOUR: RESULTS

4.1 INTRODUCTION

The intention of this study was to examine two pre-service secondary mathematics teachers' instructional practices. Drawing on Carpenter and Lehrer's (1999) framework, three critical dimensions of the pre-service teachers' instructional practice were examined: the tasks, tools, and norms. Specifically, for each pre-service teacher, the study sought to analyze the cognitive demands of the tasks, the availability and use of representations of a function, and the academic questions asked by the pre-service teacher in five consecutive lessons. Additionally, the study aimed to explore how the context within which each pre-service teacher worked influenced those practices. The study focused primarily on two aspects of the context that are noted to have an effect on instructional practices, namely the mentor and the curriculum used in the classroom.

This chapter presents the results from the analysis of the data, with Paige and Keith's stories told individually. Drawing on the richness of the data set, each story begins by describing relevant aspects of the pre-service teacher's field placement setting. Next, the details of each day's instructional practices are delineated. Each story concludes with a discussion of issues that emerged from the data regarding the pre-service teacher's instructional practices and aspects of the context that influenced those practices. Paige's story is told first, followed by Keith's.

4.2 THE STORY OF PAIGE MORRIS: BUILING A COMFORTABLE COMMUNITY

4.2.1 The Community

"And remember, our school is built on communication, cooperation, and caring. Have a great day!" Students at New Carroll Middle School are dismissed from homeroom to begin each day with this parting thought from the student anchors on the student-run televised announcements. This quote is indicative of the overall atmosphere at New Carroll Middle School: teachers, parents, and students working together to create a community where academic achievement is valued. This section further details the school, department, and team settings in which Paige Morris worked as well as her experiences at New Carroll Middle School.

4.2.1.1 New Carroll Middle School Paige describes New Carroll Middle School as a "typical middle school with middle school-type problems. The kids are wound up and things like that" (Paige, General Interview #1, March 26, 2006). One area that Paige sees as more unique to New Carroll Middle School is the high expectation of academic success for all students that is instilled by the parents. The students are "pushed to really excel" and "take really advanced math classes at the high school". She attributes this to the parents' background.

> It's a very wealthy area so most of the students come from that kind of background and their parents have, you know, high-powered jobs and are very involved in the district and within the community....I think that it's kind of just the atmosphere of that school in general; is that, you know, school is very important. I think also having their parents all have higher educations and [the students] realize, "Well, I'm going to have to go to college" and "I need to do well." and things like that (Paige, General Interview #1, 16-19).

This sentiment is echoed by her mentor, Madeline, who sees the parents' expectations and influence playing out in the level of math the students take. There are three levels of math at grade 8: 1) the technology enhanced class, which uses Carnegie Learning's Cognitive Tutor program, 2) Academics, and 3) Honors. Both the Academic and Honors classes use the Integrated 1 textbook. Madeline noted that while more than half of the students are enrolled in the Honors course, she was "not sure a lot of them should be there". She noted that the enrollment is high in those classes because of the parent's expectations and influence:

> That's like what the parents push for….When the kids register in seventh grade, when they do their course selection, it's based on teacher recommendation...teachers don't recommend over 50% of the kids for honors. Parents have the last say and [their decision] overrides [teacher recommendations]" (Madeline, Contextual Interview,32, 49-50).

4.2.1.2 The Math Department Paige considers both "student-centered activities" and technology to be highly valued in the mathematics department at New Carroll Middle School. She cites the textbooks that are used at each level as evidence. "They (sixth and seventh grades) use the Connected Math and then we use an integrated" (Paige, General Interview #1, March 26, 2006). In addition, the students have access to computer labs, mobile laptop carts, and smart boards in various classrooms. Madeline agrees with the focus on technology; however, she describes the department as "divided" regarding the philosophy of desired teaching practices.

> You know, there are four eighth grade teachers. Half of us are very much like...we think a lot like what they're doing at [the University]...you know, they should be given like...given some open-ended tasks. They should be, you know, it's okay to be confused...that's part of math. And the other half is very traditional. Teacher stands up front, the kids don't...you know, there's no group work, the kids should be in rows (Madeline, Contextual Interview, April 11, 2006).

The discrepancy in views between Paige and Madeline regarding the valued teaching practices of the New Carroll Middle School math department may be due, in part, to the fact that Paige has limited interactions with other math teachers beyond her mentor. While the department meets once a month after school, Paige rarely attends the meetings because of her class schedule at the University. Paige feels that the meetings are “not relevant” for her to attend since the issues discussed are “more general” (Paige, General Interview #2, April 11, 2006). Madeline also describes the typical meeting as informational rather than substantive. For example, the agenda may include reminding teachers about upcoming events such as conferences. She agreed that Paige does not need to attend these meetings, particularly since she does attend the department meetings that occur on teacher in-service days. During these meetings, the teachers “work on curriculum or things that the math department needs to get done”. According to Madeline, during the course of the school year, the math department had been working on “backwards planning”; that is, identifying the desired student learning (the end product) and then working to create lessons (the beginning) from that point rather than working forward from a topic list (Contextual Interview).

While Paige does talk with the other 8th grade math teacher, these conversations are typically about “trivial things” and rarely about mathematics, teaching, or learning. The exception was when Madeline was out for a six weeks on maternity leave during November and December. At that point, Paige took over the full course load. According to Derrick, Paige’s university supervisor, she was ready to assume full responsibility for the classes at this early stage in the year. He stated, “I felt very comfortable with her doing it. Some of the other people I had I would have said ‘No. It’s not a good idea’…. she’s just a natural teacher” (Derrick, Contextual Interview, lines 106-108, 110). Paige stated that during this time she would “actually talk to [other math teachers] about important stuff just because, you know, I wanted someone to help me out” (Paige, General Interview #1, line 439). Paige noted that it is difficult to talk with other math teachers during the school day because they do not have the same free periods. This is an artifact of the team format used at the school. The team format facilitates discussions among teachers across subject areas who teach the same students rather than the same subject. As a result, the vast majority of Paige's interactions with other teachers occur within her team, the Steel Squadron. The next section further describes the format and function of the team as well as Paige's role on that team.

4.2.1.3 The Steel Squadron Team The 8^{th} grade students are divided among 2 teams. Each team is comprised of one teacher from math, science, social studies, language arts, and special education. A banner bearing the team's name greets everyone who walks down hallway where all the teachers on the team are located. The hallway is decorated with student work from recent projects in various classes. Next to Paige's classroom is the team room where the team gathers twice a day, once for the 3^{rd} period team meeting and once for lunch.

The team meeting provides an opportunity for Steel Squadron teachers to share concerns about students (e.g., academic progress, plagiarism, change in behavior), discuss upcoming events at the classroom and school level (e.g., the diorama projects in Language Arts or the upcoming teacher evaluations), and to meet with parents. The teachers sit around a table during the meeting and often multi-task by participating in the discussions while grading papers. It is a collegial atmosphere where everyone's input was valued, including Paige's. She is viewed as a member of the team whose opinion on students and various upcoming events is encouraged and valued (Madeline, Contextual Interview).

While discussions about teaching did occur, they were often general and informational. For example, teachers often talked about the topics they would be teaching the next day. Madeline, who also serves as the team leader, indicated that this is an important function of the team meeting so that they can make "cross-curricular ties". She used a recent example of her conversation with the science teacher to further explain: "When he was doing um...projectile motion I, you know, said ‘well honor students just did tangent. You could tie in tangent here’. You know, so we kind of talk about stuff like that” (Madeline, Contextual Interview, 232-234). Both Madeline and Paige stated that they plan more with the science teacher since science utilizes mathematics as a tool to solve scientific problems.

> But...like at least with the science teacher, like, I know we’ll let him know what’s going on and he let’s us know what’s going on just to see if we can ever match up what we’re doing or to see if, you know, you know, “Hey, did they learn slope yet in your class?”, you know, because we just did that or...you could do this project with this now because we just taught them this kind of thing. So we do...we talk a lot with the science teacher about, I guess, more specific math stuff (Paige, General Interview #1, 449-450).

This relationship between the math and science teachers also provided Paige with an opportunity to align the math and science curriculums; that is, Paige identified the mathematical knowledge students would need to engage in various science activities. She then created a chart that displayed the information and made her work available to the other teachers. Madeline viewed this as valuable both to Paige and the science teachers.

> So she kind of looked at the science curriculum and math curriculum to see where there were overlaps. Um and the science teachers actually took and decided...he used that...her project to decide what order they should be teaching things in based on when it’s introduced in the math (Madeline, Contextual Interview, lines 193-194).

In addition to the team meetings and lunch, Paige also interacts with the Steel Squadron teachers informally in the hallways or when they stop in the room to ask a question. Paige views the teachers on the team as a resource, her source of support, and her connection to the school community. In the first interview, she described the team as, “really great people, I mean, even though they’re different subjects like, I still, you know, get ideas from them...you know, can ask them about other stuff so it’s not like I’m secluded from the rest of the school” (441-450).

4.2.2 Paige's Day

Paige described her planned and enacted lessons as being student-centered, which she described as when "almost daily [the students] have to do something in their groups, so...it might just be a simple calculator activity or finishing a couple of questions (Paige, General Interview #1, line 159). She stated that her role as the teacher is to help the students understand the mathematics, and the students role is to participate by "answering and asking good questions" and being ready and able to "explain how they got something or why they're doing what they're doing" (Paige, General Interview #1, lines 675, 678). Paige's goal is for the students to eventually be able to do the problems on their own (Paige, General Interview #1).

This section presents the results from the analysis of Paige's instructional practices. In order to establish the context, the typical structure of Paige's day at New Carroll Middle School is described, followed by an exploration of how Paige planned for, enacted, and reflected on lessons in the classroom, focusing on the 6th period honors class that served as the focus class. Specifically, the tasks, tools, and normative practices of this classroom are explored.

4.2.2.1 Beginning the school day at New Carroll The day begins for Paige at approximately 7:30 am. Upon arrival to the school, she enters the office to sign in and says hello to the secretary and anyone else in the office. All of the teachers follow this same general procedure. Paige heads up to the classroom to get ready for the day. The desks in the classroom are arranged so that the students can work in 6 groups of 5, although no class had 30 students. The daily topics and homework assignments are listed for the week on the side chalkboard, near Paige's desk. The back bulletin boards display the students' grades by identification number, the problem of the week (current problem and solution to the previous week's problem), and announcement fliers.

During the 15 minutes in the classroom before homeroom begins, Paige and Madeline talk about general issues related to teaching (e.g., getting papers graded or printing out the weekly lesson plan sheet) as well as personal matters. A few students generally drop in before homeroom to get clarification on a homework question. This is rather common place since the students at New Carroll walk to school, so they are able to arrive at any time. The homeroom teacher arrives at approximately 7:50am each morning. Since Madeline is the team leader, she is not responsible for a homeroom; however, a homeroom does meet in her classroom. Paige remained in the room during this time, but Madeline often did not. These 10 minutes of homeroom were the primary interaction Paige had with any teacher outside of the Steel Squadron. Interestingly, the exchanges with the homeroom teacher were less collegial than interactions Paige had with other Steel Squadron teachers. In every interaction Paige had with other Steel Squadron teachers, she was viewed as an equal; however, that was not the case with Paige's interactions with the homeroom teacher. For example, on the third day of observations, Madeline was at the high school for the day working with a few other math teachers planning for the next school year. When the homeroom teacher asked Paige if there would be a substitute teacher in for Madeline, Paige responded "no" and reminded the homeroom teacher that she "subbed the whole time [Madeline] was off" for maternity leave. The homeroom teacher replied, "I know, I think that's crazy" (fieldnotes, day 3, page 2). The homeroom teacher implied that Paige should not have been given such a responsibility and put in a position of such authority as an intern in the school.

Madeline is given first period off to compensate her for duties as team leader; so while the other teachers on the team only have one block available for planning (7^{th} period), Paige has two planning periods (1^{st} and 7^{th}). During these times, she grades papers, works on the computer, and talks with Madeline. These conversations are similar to those that occur before homeroom and have a very relaxed feel. For example, during first period on day 4, Paige sat at a student desk against Madeline's desk (the seat is referred to as the "sidecar" by the teachers and students) while they both graded the portfolios the students handed in the previous day. During the 42 minutes of the period, the conversation shifted between how students were doing on their portfolios and general chit-chat about their personal lives, the Language Arts teacher's upcoming last day (she is going on maternity leave), and siblings of students Madeline has had in the past. The comments about the portfolios tended to focus on students not following the directions regarding the inclusion of special items.

4.2.2.2 Planning lessons Paige has had the opportunity to think about and plan lessons for each of her classes at the year, unit, and daily levels. New Carroll Middle School provides the math teachers with a curriculum guide that outlines a broad scope and sequence for the teachers to follow throughout the year. Both Paige and Madeline stated that the teachers have a lot of individual flexibility regarding what, when, and how topics are taught.

> If we don't finish something or if we get through something too quickly or...it doesn't matter. Or if I find something...if we just feel like doing something different one day, we'll just do it....you know, no one's kind of hunching over our shoulders saying, "You're gotta, you know, finish this." (Paige, General Interview #1, lines 482- 487)

Madeline added that there is communication between teachers regarding the topic pacing and coverage, both within and across grade levels. For example, the 8th grade teachers communicate with the high school teachers to ensure that the students are exposed to the necessary topics and mathematical ideas. In addition, during the school year, New Carroll Middle School began use selected units from the Discovering Algebra series (Murdock, Kamischke, & Kamischke, 2002). Paige was involved in the discussion at the beginning of the year regarding which units would be used to supplement the current textbook.

When planning a unit, Paige begins by sitting down with Madeline and looking through Madeline's plans from the previous year, "just to get a feel for how long things maybe took or what kids had a hard time with" (Paige, General Interview #1, line 470). After discussing various options, Madeline lets Paige make the final decision regarding the pacing and content of the unit as a way to provide Paige with an opportunity to reflect on how her decision played out in the classroom. Paige completes the lesson plan sheet, which is turned into the principal at the beginning of each week. This sheet outlines the objectives, warm-up, procedures, and homework for each day (see figure 5 for an example). Paige's university supervisor, Derrick, commented that while she did provide more detailed plans when he observed her earlier in the year, he felt that she was at a point now where this level of planning was acceptable. He clarified,

> the second semester…she never really showed me anything because most of the classes aren't a formal class. So when you have group work there's not much of a lesson plan to write up. She'd have it in her head or whatever….I knew the kind of class she taught and I wasn't going to make her take the time to write up one just for me" (Derrick, Contextual Interview, lines 299-302; 309).

Periods 4 & 6 Honors: **QUARTER 3 PORTFOLIOS ARE DUE TODAY**

Objective	Graphing systems of linear inequalities
Warm-up	Review linear inequalities
Procedures	pp. 30-31
Homework	pp. 464-466 (1,2,4,6,9,11,13,18)

Figure 5. Sample of Paige's daily written lesson plan sheet

After clarifying the unit structure, Paige plans more specifically for the daily lessons. Paige uses the disposable unit “green notebooks” both as her main resource for planning and as a guide for how to structure the lesson. She described the green notebooks as “stuff from the textbook retyped with maybe some more notes added” (Paige, General Interview #1, line 461) that are copied and distributed to each student to use with their textbook. The additional notes typically involved a fill-in-the-blank definition or steps for a procedure. When asked why they use the green notebooks over the Integrated 1 textbook, she replied, “I mean, come on...like no one wants to read their math book. No one understands it, no one’s going to read the actual words so if they have the outline they can just plug the words in and be good” (Paige, General Interview #2, lines 194-196).

To plan, Paige stated that she often works through the problems in the students’ green notebooks and then writes questions that she wants to ask in the margins. She added that solving the problems in this way is helpful in planning because

> usually whatever I screw up they’ll screw up so it helps me figure out what’s gonna be difficult or um...you know just to figure out what questions do I need to ask to get them to do this. Or, you know, how much trouble are they going to have doing this? Should I introduce, you know, this as a class? Should I give them individual notes? Should they work this through as a group? Um...it basically just helps me plan out, you know, how things are going to go that day by doing it.... it actually helps me remember how to do [the problems] (Paige, General Interview #1, lines 563-569).

While Paige claimed that she “always [goes] through the notes and [does] the work” (Paige, General Interview #1, line 558), there was no written evidence of this practice. Additional evidence collected during observations also indicated that Paige did not seem to solve the problems prior to the lesson. For example, during day three of the observations, the honors students were reviewing for a test. Paige was pulling problems from the review sheets in the green books (see appendix I) and writing them on the overhead for the students to solve. Twice she commented to a student that she had not yet solved the problems. Similarly, as students worked on a project during the 4th and 5th days of observations, students asked questions about using the technology, an integral part of the project. Her responses indicated that she had not completed the task herself before class. For example, when a student asked her how to use the graphing calculator to draw the line of best fit (problems #2 and #3 on the project sheet in appendix J), Paige responded, "I don't remember how off the top of my head….Maybe try...I mean, you could try searching the 'Help' and see if you could find something (Paige, focus class transcript, day 5, lines 913-915). In neither of these instances, though, did the lack of preparation appear to interrupt the flow of the lesson. On day three, Paige solved the problems on the overhead as the students solved them at their desks. On day five, another student came to show the group how to use the graphing calculator.

As previously stated, Paige has the freedom to plan her own daily lessons. As table 6 indicates, an analysis of the tasks she used in the focus class indicated that she appropriated tasks either from the green notebook or from activities Madeline used the previous year. When asked why she made the decision to use the tasks, she stated that,

> the book does a really nice job of...you know, of explaining these so I think it was probably okay just to stick with it. Also, I've noticed that when we pull stuff from other textbooks and the kids don't really have a resource so it's kind of nice for something like this that's kind of procedural for them to have their book to kind of look at instead of us just giving them something from another place (Paige, General Interview #1, lines 602-603).

She explained that while she does refer to the textbook at times when planning, it is more to clarify what is in the green notebooks rather than to gain additional tasks or ideas for the lesson (Paige, General Interview #2).

Day: topic	Source of Task	IQA rating of source	Paige's Planned task	Relation to source of task
1: review procedure of graphing linear inequalities then groups present homework problems	Green notebook	2	2	appropriated-demands maintained
2: solving systems of linear inequalities	Green notebook	2	2	appropriated-demands maintained
3: review for test	Green notebook	2	2	appropriated-demands maintained
4: begin project	Activity used by Madeline last year	4	4	appropriated-demands maintained
5: continue to work on project	Activity used by Madeline last year	4	4	appropriated-demands maintained
Average Score on IQA		**2.8**	**2.8**	

Table 6: Summary of the IQA score for the original and planned task

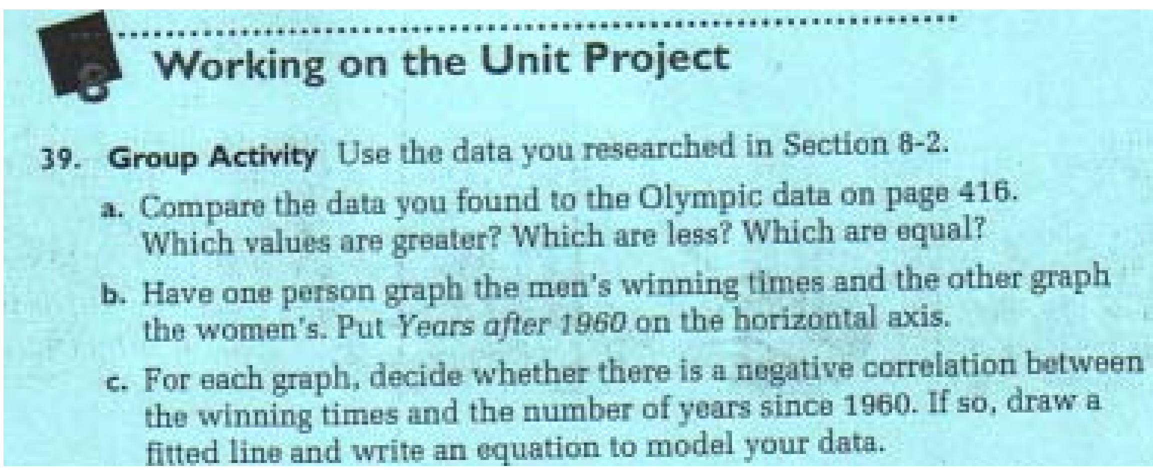
Interestingly, Paige did not realize that the project the students worked on during days four and five was actually adapted from the textbook. She stated that it came from Madeline, but she was not clear "if [Madeline] found it or if she made it up" (Paige, General Interview #1, line 643). An examination of the chapter in the textbook showed that the "project" is spread throughout the chapter; that is, the problem from the project sheet that corresponds with a particular section of the chapter is located at the end of that section. The context and purpose of the project is the same in that the students are to analyze trends in Olympic swimming winning times data using the mathematics developed in the chapter. The primary difference is that the project used in Paige's classroom combined all the questions into one packet that was completed at the end of the unit rather than spread throughout the unit. For example, figure 6 shows the introduction of the project as it appears in the Integrated 1 textbook, and figure 7 is the task for the unit project from the textbook that appears at the end of section 8.7, systems of linear equations (the topic of days one and 2 of observations). The project sheet that Paige distributed to her students is in Appendix J.


Unit Project 8

Your project is to write a news article predicting the new record-breaking time for the Olympic women's 400 m freestyle swimming event.

To write the article, you will use mathematical models to analyze past Olympic results and make your prediction. A completed project will include a data file you create to support the information you include in the article.

Figure 6. Introduction to unit project from the Integrated 1 textbook


Working on the Unit Project

39. **Group Activity** Use the data you researched in Section 8-2.

a. Compare the data you found to the Olympic data on page 416. Which values are greater? Which are less? Which are equal?

b. Have one person graph the men's winning times and the other graph the women's. Put *Years after 1960* on the horizontal axis.

c. For each graph, decide whether there is a negative correlation between the winning times and the number of years since 1960. If so, draw a fitted line and write an equation to model your data.

Figure 7. Unit project task at the end of section 8.7 from the Integrated 1 textbook

Since Paige appropriated all of the tasks, the cognitive demands of the tasks in her lesson plans were the same as the demands of the source of the task (see table 6). For example, on day two the focus of the class was to identify the solution region for systems of linear inequalities. The source of the task (the green notebook) and the planned task were both scored as a 2 on the IQA rubric, representing a low-level of cognitive demand from the students. Prior to solving any problems, the task calls for students to fill in a blank (i.e., "The ____ of two lines indicate the solution of a system if you were graphing the equation of two lines.") and complete a sentence ("The solution for a system of inequalities consists of: "). Paige completed both in her notes as, "intersection" and "the overlapping shaded regions", respectively. The task then instructs students to graph the system of inequalities, a procedure they learned in the previous section. The focus is solely on producing the correct answer by identifying the solution as the section where the two shaded regions overlap.

This aligns with how Paige described her plan for the lessons. During General Interview #1, she noted that, "this is more procedural stuff so hopefully I can kind of get them to understand the procedures and why they work, and then they can do them on their own" (line 658). She planned to help the students towards this goal by "just modeling the problems. So I'll help them...I'll walk them through the notes for the...for a lot of it" (lines 661-662).

The task as it appeared on the project sheet (see appendix J) and in the lesson plan for days four and five were scored as a 4 on the IQA rubric, representing a high-level of cognitive demand from the students. While there were some explicit procedures for the students to follow, the focus was on using the information from those procedures to identify patterns, make conjectures, and justify the conclusions by using appropriate mathematical evidence. For example, Project Problem #2 was as follows:

> Using a TI-83 calculator, create a scatter plot of the data. Use the years after 1960 as the control variable and the women's 400m freestyle swimming times as the dependent variable. Use the graphing calculator to find the equation of the line of best fit.

After completing additional graphs, the students had to analyze the trends in the swimming record data, make predictions about when the women's winning times would equal the men's , and finally predict the new record breaking time for the women's event.

4.2.2.3 Enacting lessons Paige's mathematical goals for the series of lessons in the focus class are summarized in table 7. During the set-up and enactment of the lesson, Paige maintained the cognitive demands of the task as established in the lesson plan. The tasks for days 1-3 were each set-up and enacted at a low-level of cognitive demand; that is, the lessons focused on using a given procedure for the purpose of producing the correct answer rather than developing a conceptual understanding of the underlying mathematics. On the other hand the tasks for days four and five- the Olympic Swimming project- was set-up and implemented at a high-level of cognitive demand. Paige's average IQA score for both the set-up and enactment of the tasks was 2.4. These results are summarized in table 8. This section further examines each of the tasks as set-up and as enacted in the focus class. Specifically, the cognitive demands of the tasks, the questions, and the representations available and used in the lesson will be explored.

Day	Goal
1	My goal is to finish graphing linear inequalities and have them understand the solution region and just the general procedures of graphing.
2	We're graphing systems of linear equations so to understand what the...I guess, shaded regions mean.
3	My goal [is] to review kind of the concepts we did earlier in the chapter. So, modeling situations with equations and creating equations for a line based off of different information, horizontal/vertical lines. Just things they hadn't seen in a while.
4	PM: Oh...Um...just to introduce them to the project…And then get them started on the research. JM: What's the project about again? PM: It kind of just groups together a lot of the stuff we did in this chapter um...like systems and uh, using data representation, things like that.
5	(Time constraints did not allow for a pre-lesson interview on day 5.)

Table 7: Paige's goals for each day as given in the lesson centered interview

Day: topic	Original	Planned	Set-up	Enacted
1: review procedure of graphing linear inequalities then groups present homework problems	2	2	2	2
2: solving systems of linear inequalities	2	2	2	2
3: review for test	2	2	2	2
4: begin project	4	4	4	3
5: continue to work on project	4	4	4	3
Average Score on IQA	**2.8**	**2.8**	**2.8**	**2.4**

Table 8: Summary of the IQA scores for the original task, planned task, set-up, and enactment of the task

4.2.2.3.1 Day One: low-level of cognitive demand Both the set-up and the enactment on day one were scored as a 2 on the IQA rubric since the focus of each was on practicing a specific procedure regarding the graphing of linear inequalities (see appendix G for a copy of the task). Additionally, students were not pressed to provide anything more than the correct answer. During day one, Paige launched the lesson by reviewing with students the steps for graphing linear inequalities they learned in the previous lesson. Students then were assigned specific problems from the corresponding homework to put onto chart paper. After approximately 17 minutes, each group presented their solution to the given problem. Four groups presented their solutions, with each explanation outlining the same steps reviewed in the launch: find two points from the equation; plot them on the graph, using the sign of the equation to determine if the boundary line is solid (great/less than or equal to) or dashed (greater or less than); use a test-point to determine whether to shade above or below the boundary line. Following the explanations, Paige would ask for questions. If there were none (3 out of the 4 times), the next group would present.

The graph, equation, and table were the main representations used throughout the lesson, and the students had access in the class discussion to 4 sets of tables, graphs, and equations. There were 12 conversations where the students made connections between these representations; however, 10 of the connections were procedural in nature. For example, the students determined if the boundary line on the graph should be solid or dashed based on the sign of the inequality when it is written in slope-intercept form. There were 2 conversations, however, where Paige asked connecting questions that provided the students with an opportunity think critically about the underlying mathematics. For example, a group presented an incorrect solution in that they did not identify the correct boundary line. This prompted another student to ask about using points on the boundary line to determine the solution region to the linear inequality. Paige began the discussion by asking two connecting questions that provided the students with the opportunity to think and reason about the role of the boundary line and the rationale that underlies the procedure of testing points not on the line to determine the solution region.

> PM: Why shouldn't you test a point that's on the line? Why do you think you shouldn't test one of those?
>
> St: 'Cause it's on the line, it doesn't show you whether...if it's true or false it doesn't matter because then …it's gonna be on the line (focus class transcript, day 1, lines 889-891).

The discussion continues with students stating that the points on the line are always solutions to the boundary equation. Paige summarized the conversation, adding that the convention of making the boundary line solid or dashed based on the inequality sign (i.e., greater than is dashed, greater than or equal to is solid) is used to decide if in fact the points on the line are included in the solution.

During the lesson, Paige asked a total of 64 questions (see table 9). Almost two-thirds of the questions were monitoring, such as “So...how are you going to figure out where to shade?” and “So here...What’s the boundary line of 4y-3x<12? How do you figure out the equation for the boundary line?” (Paige, focus class transcript, day one, lines 540, 828-829). Few questions (4.7%) asked the students to make connections to the underlying mathematical ideas of the task.

Day: topic	Tuning	Monitoring	Connecting	Total
1: launch to review procedure, then students present HW problems	21[8] (32.8%)[9]	40 (62.5%)	3 (4.7%)	**64**

Table 9: Questions asked during the set-up and enactment in Paige’s classroom on day 1

<u>4.2.2.3.2 Day Two: low-level of cognitive demand</u> Paige’s goal for day two was for the students to “understand what the...I guess, shaded regions mean” for systems of linear inequalities (Pre-lesson interview, day 2). To accomplish this goal, she focused students’ attention on a procedure very similar to the one students practiced on the previous day for graphing one linear inequality. As a result of the lesson again focusing on practicing a procedure, the IQA score for both the set-up and enactment was a 2 (see appendix H for a copy of the task).

Paige began the class by asking tuning questions linked to students’ prior knowledge, such as “So...remind me...the solution to a system of equations is what?” and “So the line is either solid or dotted depending on the inequality symbol but then what did we have to do after that to show

[8] Number of questions coded as such – ie. 21 questions out of 64 total coded on day 1 were tuning

[9] Percent of questions asked that day- ie., 32.8% of questions on day 1 were tuning

where the solutions were?" (focus class transcript, day 2, lines 60 & 96). She then proceeded to tell the students (language representation) the goal for the day:

> So we're going to combine what we know about linear inequalities and combine what we know about systems of equations. And what happens is, that the solution to a system of inequalities will be an overlapping shaded region. So you'll have two inequalities with two different shadings and your solution region will be wherever those intersect. And that will make much more sense once we do an example. So that will be the overlapping shaded region (focus class transcript, day 2, lines 101-106).

Similar to day one, the graph and equation were the main representations used throughout the lesson. The students had access in class via the green notebooks to 4 equations from which they followed the same procedure to make the 4 corresponding graphs. The first two problems were completed as a whole class activity, while the last two were completed individually as Paige walked around the room. While Paige gave the option of creating a table from the equation to make the graph, the majority of students (and the preference of the teacher) was to use the "short-cut" method of using the slope and y-intercepts from the equations to go directly to the graph. As a result, a table was only utilized once. The student stated that the table was her preferred method, because she didn't like the short cut. This occurred in a private discussion between Paige and a student, and this discussion was not made available to the whole class. The purpose of the table during this discussion was to create points from which the student could then follow the procedure for graphing a line.

A contextual problem was available in the textbook for homework; however, there were no connections made to the context during this class discussion during this or proceeding days. In addition, the context was not needed to answer the homework question. The remaining homework problems from the textbook also involved the graph and equation. For three of the problems, students were given a graph and equation and asked to determine if the given point is a solution to the system. For the last four problems, students were given equations and asked to graph the systems to find the solution region by following the steps outlined in class.

Overall, there were 22 conversations where the student made connections between representations, 7 of which were prompted by connecting questions. Most of the connections were between the equation and graph and focused on a procedure rather than a concept, as did the monitoring questions she asked during the whole class discussion and individual work. For example, the following exchange occurred during the set-up of the task:

> PM: So to graph it, the y intercept is positive four. One, two, three, four. Okay? And before I figure out the line, I need to know how to draw it. Should it be dashed or should it be solid? Kyler? Should this one be dashed or solid?
> St: Solid.
> PM: Why?
> St: Because it's [the sign in the equation] a...greater than or equal to.
> PM: Good (focus class transcript, day 2, lines 125-135).

This exchange was typical of the conversations that focused on monitoring the students' knowledge of a procedural connection between the representations.

Additionally, there were 14 conversations where the teacher made connections between the representations, typically the equation and graph. These connections were in the form of statements, and again focused largely on the procedural aspects of the connections. An exception occurred during a class discussion about the inequality "$y < x + 4$". A student indicated that the boundary line is dashed, which prompted the following exchange:

> PM: What does the dashing mean?
> St: Well, it means that y is less than, like it's not greater than or equal to.
> PM: Okay. So the points on that line are not going to be solutions (focus class transcript, day 2, lines 297-300).

During this exchange, Paige, not the student, stated a key mathematical idea regarding the interpretation of the dashed line on the graph--whether or not the points on the line satisfy the conditions of the equation.

Paige asked the most academic questions on day two, asking 121 questions. This is almost double the amount of the next highest daily total (64 questions on day one). As indicated in table 10, approximately 80% of the questions served to monitor students' understanding of the procedure. As stated earlier, the tuning questions occurred at the beginning of the lesson. The remaining 10% of the questions asked were connecting questions. For example, while students worked at their tables to graph two parallel linear inequalities (see figure 8) Paige circulated the room. She stopped at one student's desk, looked at her paper, and asked the student why there was no solution to the system of linear inequalities. After the student responded by stating the shaded regions do not overlap, Paige asked, "So you think if I picked...do you think there's a point I could pick, x, y that would make both of those true?" (focus class transcript, day 2, line 693). After pausing, the student simply responded, "nope". However, it is not clear from the student's response if the student did, in fact, make connections as to why there would be no point to satisfy the conditions about which Paige asked. While Paige accepted the student's response and did not push her to further clarify or explain her reasoning, the initial question did provide the student with an opportunity to advance her current thinking and understanding by prompting further reflection and analysis of mathematical relationships.

Day: topic	Tuning	Monitoring	Connecting	Total
2: solving systems of equations (teacher directed "lecture")	12 (9.9%)	97 (80.2%)	12 (9.9%)	**121**

Table 10: Questions asked during the set-up and enactment in Paige's classroom on day 2

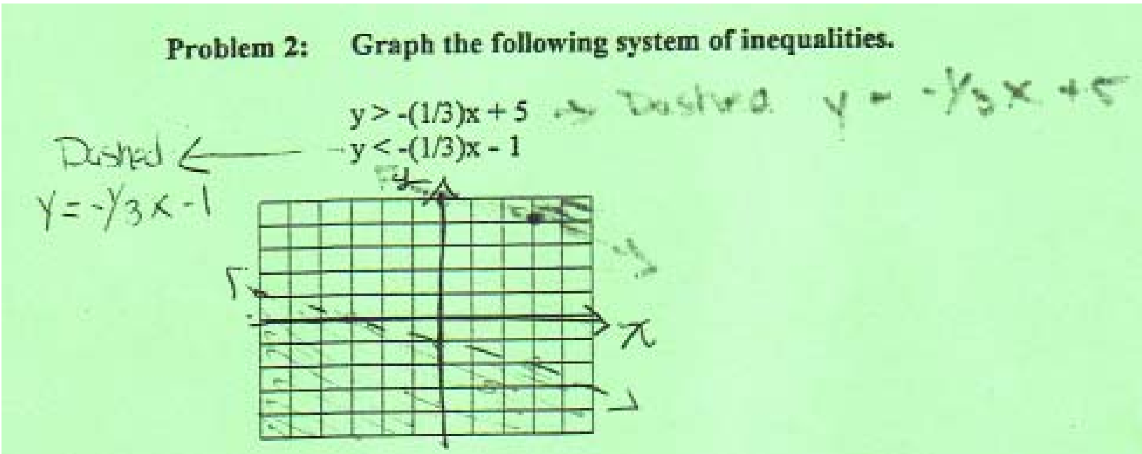


Figure 8. Problem #2 from day two of Paige Morris' class

<u>4.2.2.3.3 Day Three: low-level of cognitive demand</u> The focus of day three was to review for the test the following day. To accomplish this goal, Paige presented a total of nine problems from the review sheets in the back of the green notebooks throughout the class. After the students solved the problem, either individually or with a partner of their choosing, they wrote their answer on an individual white board. Paige would call for "white boards up", at which point she scanned the room to check the students' answers. The task was scored as a 2 on the IQA since the focus was on applying previously learned procedures to obtain the correct answer (see appendix I for a copy of the task).

The equation was the main representation used throughout the lesson. The students had access in the class discussion to eight different equations. Five times the equations were the starting point of the problem: three equations in standard form from which the students had to write in slope intercept form; two equations in standard form from which the students were to find the x and y intercepts. The remaining three equations were produced as the solution to a problem: twice the students were given two points and they were to determine the equation for the line containing both points; and once the students were to determine an equation that model a given situation. Language and graphical representations were used once, both on a problem that required finding the intercepts. The discussion centered on the axis on a graph, but originally, no graph was available, since the expected method to find the intercepts was to work with the equation rather than locate the intercepts on the graph. Eventually Paige did sketch a graph, but she made the connections between the graph and the equation by focusing on the procedure. A contextual representation was available one time at the end of the lesson. The purpose of the problem (see figure 9) was for students to write an equation that modeled the situation. The bell to end class rang approximately one minute after the problem was given, so the students gave the solution as they were walking out of the classroom. As a result, even though the given equation was correct, there was no discussion that revealed students understood the relationship between the information in the problem (i.e., starting temperature and rate of increase) and the equation (y-intercept and slope). There were no meaningful connections made between any representations by the students during the lesson.

> The temperature of a laboratory is -210º C, and it is rising at 7ºC each minute. (control variable: time; dependant variable: temperature)

Figure 9. Contextual problem used on day 3

As illustrated in table 11, Paige asked a total of 48 questions during the lesson, 46 of which served the purpose of monitoring the students' understanding. These questions occurred after the students showed their answer on the white boards and focused on recalling the steps for procedures, such as "What's the second step to get y by itself?", or on determining the answer to a computational problem, such as "What's 7 divided by 4?" (focus class transcript, day 3, lines 192, 114). Additionally, Paige also provided "hints" at various times and even directly told the students how to do the problems. For example, on the third review problem the students were to find the x- and y-intercepts for the equation, "-2x + 7y = -28". Approximately 30 seconds after presenting the problem, Paige provided the following hint:

> For those of you who are stuck, remember x-intercept will always look like this...over an x value, up zero. Y-intercept will always look like this...over zero, up a certain amount in the y direction. That may be a clue on what you need to do to that equation. Look for the x intercept (focus class transcript, day 3, lines 407-410).

As she talked, she wrote the corresponding ordered pairs on the overhead (i.e., (x, 0) for the x-intercept and (0, y) for the y-intercept). Later, as she scanned the white boards to check the students' answers, she noticed a few students had combined the intercepts into one coordinate. She stated,

> One of your values has to be setting at zero. For an x-intercept, you need to make y a zero. You have a y-intercept you make x zero. Two separate coordinates. One has to be over x up zero. Two...no, that's...that's not gonna cross either the x or the y axis. You're combining your x and y intercept into one coordinate where there should be two separate ones (focus class transcript, day 3, lines 431-437).

Day: topic	Tuning	Monitoring	Connecting	Total
3: review for test- use problems from green book review and show answers on whiteboard	0	46 (95.8%)	2 (4.2%)	**48**

Table 11: Questions asked during the set-up and enactment in Paige's classroom on day 3

4.2.2.3.4 Days Four and Five: high-level of cognitive demand The focus of days four and five was to introduce the chapter project (see appendix J) and provide students with an opportunity to work with their group on the project. This task represents the only task that was planned, set-up, and implemented at a high-level of cognitive demand. On both days, Paige set-up the task in a way that provide students with opportunities to solve a cognitively demanding task that required the students to identify patterns, make generalizations, support their claims with mathematical evidence, thus scoring a 4 on the IQA rubric for the set-up. However, while the cognitive demands of the task remained high during the enactment (i.e., there was potential for the students to engage in complex thinking as they progressed through the project sheet), there was no explicit evidence of student's thinking and reasoning made public since there was no class discussion and Paige's interactions with the students about the mathematics was limited. Since there was no evidence of the cognitive demands declining, the implementation for both days scored a 3 on the IQA. The details of both days are further explained below.

On day four, Paige spent approximately seven minutes introducing the project by having a student read the directions, which included the context of the problem, directions, and timeline for the project. Students then created self-selected groups of 2-3 students, gathered laptops and other materials, and began to work on the project.

The representations available while students worked on the project included graphs, equations, context, and tables. On the project sheet, the students had access to the context (Olympic 400m Freestyle Swimming), a table that had the years and winning times for men and women from 1960 – 2004, and 2 equations for a high school swim team's data. The directions asked the students to make 2 graphs- one for the Olympic data and one for the high school data. The table served as the "jumping off point" for the project in that the graph and subsequent line of best fit were developed from the table. The students are asked to make general observations about the data in the table and to make predictions as a way to enter the problem (the brainstorming section). Students were then asked to make sense of the trends in the table in terms of the real life context (e.g., "Do you think the records can continue to improve forever? Why or why not?"). The project provided multiple opportunities to connect representations and make sense of and extend students mathematical reasoning and understanding. For example, Question 1d on page 5 of the project sheet prompted students to make connections between the graph and table; question 4 prompted students to interpret the solution of the linear system (graphically or equations via substitution) in terms of the context; and the final part of the project required students to "analyze trends" and "make predictions". However, very few representations were discussed by Paige throughout the class. In fact, Paige was more "hands-off" during these two days, asking a total of only 44 questions between both days (see table 12).

Day: topic	Tuning	Monitoring	Connecting	Total
4: begin project (students work individually or in groups)	0	28 (93.3%)	2 (6.7%)	**30**
5: continue to work on project	0	14 (100%)	0	**14**

Table 12: Questions asked during the set-up and enactment in Paige's classroom on days 4-5

The conversations between Paige and the students during the group work focused on class activities not related to the mathematics of the task (e.g., feedback on the graded tests, getting groups set), non-academic talk (e.g., daylight savings time), or technology conversations that came about because of the project (e.g., discussing the graphing website the students found on-line). When the conversations were about the mathematics of the project, Paige tended to initiate them with questions. The vast majority (93.3% on day 4, and 100% on day 5) of questions asked during the two days was monitoring and served the purpose checking in on groups' progress. Paige usually accepted the student's response of "fine", "ok" , etc. and moved on to another group. For example, the following exchange between Paige and a student was typical of the conversations:

> PM: So you understand what that question is asking?
> St: I think so.
> PM: So they just mean, if you had...how could you get two intersecting, two parallel or like the shaded region? (focus class transcript, day 4, lines 1071-1073).

After Paige restated the question from the project sheet, she moved to another group.

4.2.3 Emerging issues from the analysis

Paige's story began with a quote from the student announcements that reminded students about the community of New Carroll Middle School. The theme of "building a comfortable community" was pervasive throughout Paige's experiences with both her mentor teacher and university supervisor. Paige, Madeline, and Derrick each noted that Paige has developed a good relationship with the students and staff at New Carroll Middle School. As discussed previously in section 4.2.2.1, Paige was viewed as an equal in the community by the vast majority of teachers. Overall, everyone- Paige, Madeline, Derrick, and the other teachers- expressed that Paige was doing a "good job" teaching. Derrick stated that '[Paige] was on top of things right from the very beginning" (Contextual Interview, line 75). For example, he commented that when Paige took over all the classes while Madeline was on maternity leave, "Paige did an excellent job. I was very impressed, as a beginning teacher, of the job she did handling all that" (Contextual Interview, lines 39-40). Similarly, Madeline expressed that she also was confident in Paige's ability to take over 2 ½ months after beginning her internship. Madeline noted that "[Paige has] got the basics right off the bat so I was not worried about her taking over when I left at all" (Contextual Interview, line 387).

Following each of the focus lessons, Paige felt confident that she met her intended goals for each day. For example, at the end of day one, Paige stated that the students "did a really good job of explaining their work so I feel like they probably got it" (lesson centered interview, day one). She described both her role as the teacher and the students' role as going "pretty much as I planned" during the lessons (Paige, General Interview #2, line 478). Throughout the focus lessons and interviews, a few issues emerged regarding Paige's instructional practices. These issues, which are discussed in the next section, were identified by reviewing the fieldnotes for common themes. The transcripts of interviews and focus classes were then coded for evidence of each theme: co-teaching, having fun, remembering, telling, and feedback.

4.2.3.1 "Co-teaching" during the day One theme that permeated the observations was the notion of "co-teaching". This was most apparent in the technology enhanced class during second period. Paige stated that the technology enhanced class is "supposed to be another academic level" class, but that it is different because, "for the most part, all of the special ed kids are in the cognitive tutor class" (Paige, General Interview #1, lines 93-94). As a result, the special education teacher is present for every class.

As the students entered the room, all three teachers walked between groups to remind them to open their books to a particular page, to hand in homework, or to get a laptop. Both Paige and Madeline made general comments to the class at the beginning of each day. For example, on day five, Madeline announced that students should turn in their homework and get a participation sheet for the week. This was immediately followed by Paige reminding the students to write their homework assignment in their agendas (calendars given to each student from the school for this purpose). Madeline began the class by “review[ing] the big idea about the distributive property that [the students] talked about on Thursday” (fieldnotes, day 5, p.8). As Madeline progressed through the review, the special education teacher interjected with questions for the students to answer. For example, Madeline asked the students what it means to combine like terms. After a pause with no response from the students, she writes “6x+2x” on the board.

> Madeline: Can we combine them?
> SpEdT: (after another long pause) Are they like terms?
> Student: Yes.
> SpEdT: So can you combine them?
> Student: Yes.

Madeline continued the discussion by looking at another example where the terms cannot be combined (6x+2) and comparing the two expressions. The students then began working at their desks and all three teachers circulated to help groups and individual students.

This idea of one teacher interjecting while another was teaching also occurred in the academic classes (5h and 8th periods) and the honors classes (4th and 6th periods), although it looked somewhat different in each class. Madeline was the main teacher in the academic class, and while Paige did interject while she was teaching, it was more with respect to focusing a student’s attention or repeating directions. Typically during the academic classes, Paige sat at Madeline’s desk and graded papers or worked on the computer.

Paige was responsible for the honors classes. Similar to the way Paige interacted with the academic classes, Madeline often re-focused students, clarified a question from a group, or worked with a student during honors classes. However, one difference between the interjections of Paige and Madeline was that each day, with the exception of day 3 since Madeline was not in the school, there was at least one instance (seven times total) where Madeline interjected during the class discussion to further push or clarify the mathematics. For example, during the lesson on day two in 6th period, Paige was leading a discussion on the solution region of systems of linear inequalities. After the students graphed both linear inequalities, Paige asked them what they though the overlapping region represented. It was this point that Madeline pushed further by interjecting.

Paige:	So anything in the blue region would make that first inequality true. So what do you think about the overlapping region that I kind of trapazoided in here? What do you think about that region...where it overlaps? If I picked a point from in there? Go ahead, [female student].
Student:	It would be true for both of them?
Paige:	It would be true for both of them. So this, this whole section in here are the solutions to the system of inequalities. Did I spell that right? In...okay.
Madeline:	How many solutions are there?
Student:	Infinite?
Student:	A lot.
Student:	How ever many points there are?
Madeline:	A lot. [male student] said, “A lot.” and [female student] said, “However many points there are.” How many points are there in this, you know, purple solution region?
Student:	(inaudible).
Madeline:	Why?
Student:	(inaudible)
Madeline:	Sure.
Student:	Alright. Because it’s not...just straight...it’s continuous because of the way that a block can be an infinite amount of points (xxx).
Paige:	Nice!
Madeline:	Did everyone understand what she said?
Student:	Yeah.
Student:	Yeah.
Paige:	So in between each of those, you know, tick marks they might each represent one but you know there are tons of little decimals right there that we could split them up into (Focus class transcripts, day 2, lines 253-274).

Paige and Madeline see this type of "co-teaching" as beneficial both to the students and to them as teachers. Madeline expressed that having at least "two experts" in the room allows for a smaller student to teacher ratio during group work as well as provides opportunities for individualized instruction, particularly if a student has missed a few days of school. While she sometimes tries to hold back to allow Paige the full experience of teaching, she noted that, "we do a lot of co-teaching….We're both working together and I'll sort of jump every once a while...and the kids feel comfortable going to either one of us" (Madeline, Contextual Interview, lines 353-356). Paige echoed this idea of working as a team and its benefit to her.

> It's like having someone to cover your back cause like, "Oh, I forgot that" or "Oh, that's a great way of thinking about that" so...it's always nice to have...I mean, when you're up there and you're like, "Oh…no one understands me" and someone can maybe just see it from, you know, standing back and say something or...I like it, it's nice (Paige, General Interview #2, line 97).

Madeline stated that her primary role as a mentor teacher is to "provide [Paige] with a model in good teaching, which I hope I'm doing" (Madeline, Contextual Interview, line 406). One way of accomplishing this is to use the co-teaching model. Paige does in fact view her teaching practices as very similar to Madeline's, from the organization of the lesson to the way in which she enacts the lesson in the classroom; however, she further clarified that she doesn't purposely try to model what Madeline does, "it just kind of worked out that way" (Paige, General Interview #1, line 332). Paige explained that she "never really just sat and observed", but rather was "pretty involved in all the classes" from the beginning of her internship (Paige, General Interview #1, lines103, 108). Paige also added, though, that over the course of the year she felt that Madeline's role changed from providing a model of how to enact a lesson to being a resource on which she can draw when needed. "I think more now I would seek her out to ask her something than maybe her show me something" (Paige, General Interview #2, line 65). The next section further described Paige's instructional practices.

4.2.3.2 Two repeated phrases: "Have fun" and "remember" One non-mathematical focus for Paige was for the students to have fun. During the first general interview, there were five instances where Paige mentioned designing activities or lessons for the students to have fun and twice during the second general interview. To accomplish this goal, Paige planned to use the Smartboard, graphing calculators, and colored pencils, stating that, "we try to do things that they think are cool or just using a colored pencil makes them excited so, if we can find something little to trick them into thinking they're having fun then, they're okay" (line 57). The focus was not on using the tools for enhancing mathematics, but rather to present the material in a different way to grab the students' attention. This idea was also evident in the implementation of the lessons. For example, during day two in the focus class, a student stated that he did not want to graph the inequalities. Paige responded, "but you can use colored pencils" (Focus class transcript, day 2, line 802).

Paige also emphasized the notion of "remembering". Throughout the focus classes there were 30 instances of Paige prompting the students to remember either a classroom procedure, mathematical procedure, or a prior experience. This theme was also apparent in the other classes Paige taught (field notes). Of most interest was the use of "remember" in reference to the mathematics of the lesson. This involved Paige either prompting the students to recall a procedure or encouraging them to memorize a new procedure or short-cut. For example, at the beginning of class on day five, Paige worked with a student to review the problems he missed on the test. She told the student, "if you remembered 'undefined' means it's a vertical line, you could just look at this and say, 'Oh, it's x = negative 4'" (focus class transcripts, day 5, line 266).

During this exchange, the focus is on "remembering" or recalling from memory a specific characteristic of a vertical line.

4.2.3.3 Teacher as teller A third theme that emerged from Paige's instructional practices was Paige telling the students the mathematics, thus being the owner of the mathematical knowledge. During the five focus classes, there were 294 statements made by Paige that were coded as telling. The majority of these statements focused on telling the students how to solve a particular problem. Typical examples include statements such as, "a good way to graph...to figure out what the boundary line is, you can make a table and graph that line", (focus class transcript, day 1, line 473) and "you wanna see the rate of increase so you'd wanna start with the higher year. Right. And see how much up it goes from this year to this year" (focus class transcript, day 4, lines 805-807). There were a few occasions that Paige told the students the key mathematical concepts or connections. For example, during day two, students are independently solving a system of linear inequalities with the same slopes. Paige discussed the solution with student at her desk:

> PM: So, what do you think about this one then. Where is the solution?
> St: Um...there isn't one?
> PM: There isn't one. How come?
> St: Um...because they don't...like...touch each other.
> PM: Exactly! There's no overlap, so there's no solution. Okay?
> St: Okay.
> PM: So there's no point that will make both of those true at the same time. Good. Yep (focus class transcript, day 2, lines 661-672)

In this example, while the student identifies that solution regions for each inequality do not touch, it is Paige who tells the student what this lack of overlap means mathematically. While there were 28 instances where Paige did encourage the students to take ownership or make decisions, they tended to revolve around providing the students with two procedures to solve a problem and letting them choose one (e.g., create a table to graph the line or use the "shortcut" with the slope), encouraging students to ask questions if they did not understand, or non-mathematical issues such as choosing groups.

4.2.3.4 Feedback The final theme that emerged was the idea of the amount and type of feedback that Paige receives from both her mentor and her supervisor. Both Madeline and the supervisor stated that Paige was receptive to feedback. Madeline stated that while she does formal evaluations as required by the University,

> most of [the feedback] is informally, though, you know, just kind of like on a day to day basis. Like, "You did that really well" or "Maybe tomorrow you should re-emphasize this" or "Maybe tomorrow the kids need some extra time to do this", that sort of thing (Madeline, Contextual Interview, lines 430-431).

Paige also noted that the typical conversations between them about her teaching are helpful, and

> usually start out with like, something like, "Wow! They really, you know, understood this, this and this. Or they didn't get this certain point." and you know, it'll go from there maybe and, "Well, maybe tomorrow we could do this." Or, "Maybe we'll you know, skip that and only test them on this." or, you know, something like that. And then try to...it's usually just kind of quick reflection on what happened and try to figure out where to go from there (Paige, General Interview #1, lines 381-384).

This aligns with the conversations between Paige and Madeline that were noted during the observations.

Additionally, Paige receives feedback from Derrick, her university supervisor. Both Paige and Madeline describe Derrick as a "nice guy". Paige stated that "he always gives me a, you know, a good perspective on what's going on" (Paige, General Interview #2, line 133). Derrick thought Paige readily accepted and acted on his feedback. He stated that while Paige

> was pretty good, she could always use some advice so I'd talk to her maybe about handling a problem student or maybe a different way to present something….we'd sit down afterwards and...we would talk

> about the lesson and we'd talk about anything else that came up (Derrick, Contextual Interview, lines 153-154).

Madeline felt that Derrick did provide Paige with "good reinforcement and then...usually one or two things that she should work on for the next time" (Madeline, Contextual Interview, line 551). However, she also noted that sometimes the feedback was not focused on the particular lesson. She discussed a time when Paige shared with her Derrick's written comments from an observation, noting that "she gave me the paper that he sent and it said... 'Work on getting job interviews done' Real good feedback, I had to laugh" (Madeline, Contextual Interview, line 549).

4.3 THE STORY OF KEITH NICHOLS: BEING HELD TO HIGH STANDARDS OF SUCCESS

4.3.1 High Standards

Success is emphasized and expected at Baskerville Middle School by teachers, parents, and students. For example, Keith noted that the students "have high expectations...[and] I'm sure that comes from the parents. Most students are motivated by academic success" (Keith, General Interview 1.1, lines 35-37). Darcy emphasized that "we take education very seriously here…that's a high standard that we possess" (Darcy, Contextual Interview, line 11). The notion of high standard of success permeated Keith Nichols' experience at Baskerville Middle School.

This section further details the school, department, and classroom settings in which Keith worked as well as his experiences at Baskerville Middle School.

4.3.1.1 Baskerville Middle School Keith described Baskerville Middle School as having a reputation of being “a very wealthy district and that’s true. But there...I guess there’s a wide range of [socio-economic] backgrounds” (Keith, General Interview #1.1, lines 31-21). He explained that some of the students are from extremely wealthy backgrounds, while others cannot afford basic necessities, mentioning that one of his students was homeless for a period of time. Both of his mentors, Darcy and Michelle, described the school similarly. Michelle noted, though, that one advantage of the school is that, “if we need something as a teacher for a resource for our kids, we can usually get it pretty easily” (Michelle, Contextual Interview, line 354). The resources she discussed ranged from eye glasses for students to technology to use in the classroom.

All three teachers discussed the expectations the vast majority of parents have for their children. Keith stated that “parents push [the students] pretty hard for the most part” (Keith, General Interview #1.1, line 27). For example, parents have input on a student’s placement in a particular course; that is parents can, and sometimes do, override teacher recommendations in order to place the student in a “higher” math class. Darcy explained that while she definitely sees the influence of the parents, she also sees a lot of motivation coming from the students themselves. Michelle described the students as “highly motivated” (Michelle, Contextual Interview, line 42). However, Keith views the way the motivation plays out in the classroom as different across classes. He described the differences between the classes he teaches:

> Algebra kids are motivated by learning. They just want to learn, learn, learn, learn, learn. They wanna do problems, do problems, figure out how to do a harder problem and they are motivated to talk with each other and help each other solve problems. Whereas the

> seventh graders are a lot less active in their learning. They're more willing to just sit there and wait for you to tell them how to do something. You have to motivate them a little more. Also there is a much wider range of ability in my seventh grade class. There are some kids that I think should probably be a little lower or at least could be helped by being lower based on their effort, and there are some that I know could have been higher but chose not to be (Keith, General Interview #1, lines 104-111).

He attributed this difference in motivation to the fact that the algebra students are "better at math. They've traditionally, they have done very well in school and they're motivated by that to do...to continue doing well" (Keith, General Interview #1.1, line 132).

4.3.1.2 The Math Department Michelle stated that the math department at Baskerville Middle School has two meetings per month. The first meeting involves all the teachers in the department. Keith described these meetings as a forum for general issues, with "the head of the math department just telling us what we need to do and people asking questions if they don't understand." He noted that his role is "more of an observer" during these meetings (Keith, General Interview #2, lines 21-22). Both of his mentors indicated that this lack of involvement at the larger meeting was not surprising for a pre-service teacher since the issues discussed often transcend one particular school year. The second monthly department meeting involves groupings of math teachers by subject (i.e., 6^{th} grade or algebra). The focus of the subject meetings is to

> talk about where everyone is in the curriculum and what we thought was particularly good or bad in something. What we thought maybe we could skip or what we thought we needed to back up and do over (Michelle, Contextual Interview, lines 55-56).

For this reason, Michelle noted that Keith's participation would be appropriate in this venue; however, similar to Keith's description of his own participation, she noted that, "he doesn't usually have much to say" (Michelle, Contextual Interview, line 128).

During the last few years the mathematics department at Baskerville Middle School has undergone a transition. The changes have impacted the general philosophy of valued teaching practices within the department, the composition of the staff, and the curriculum used in the classrooms. The shift centers around moving away from traditional teaching practices towards those that are more reform oriented (Darcy, Contextual Interview; Keith, General Interviews 1 & 2; Michelle, Contextual Interview; Nicole, contextual Interview). Darcy stated that there is a large focus on

> providing high level tasks. You know, we're promoting multiple representations....try to make the connections to real life,…. working with other individuals, being able to express mathematically,…verbally, written,…formula or… stuff like that (Darcy, Contextual Interview, lines 88-92).

Darcy has been a central figure in the change. She admits to being a leader in the department, but describes herself as "more of a quiet leader" (Darcy, Contextual Interview). She compared her way of facilitating change in the department to the way the district had tried previously:

> a lot of times when they try do stuff here as... a whole district, they tried to just like throw it on us, like a whole big thing and...people are just not going to deal with that....I try to make my connections with like individuals first versus the department and try to...kind of see my project or my thing along….If I can help a couple of other people and try to show them some things that I've learned or some things I've discovered, some techniques I've found,…then I feel…then maybe they'll keep using it and it'll…spread (Darcy, Contextual Interview, lines 106-108).

Three years prior to having Keith as an intern, Darcy took a class from Nicole at the university. During that time, Darcy began using some of the pattern tasks from that course in her own classroom. She described the transition from only doing the tasks in her room to leading professional development activities for the staff.

> When I was learning about the pattern task when I first came to [the university] … I just did it on my own and ... people would come observe me and I would do...one of those for that day...and they're like, "Ooh, can I have that?" and I'm like, "Okay. Sure." And then the next thing you know people are observing me more and they're like, "I want those." and the next thing you now I'm giving like all my tasks that... that I've collected to other people and they start doing it but they weren't sure how to do it because they thought they could just kind of whip it up there and do it … because they're math...so then I was doing little mini- workshops… showing them some techniques and some kind of questioning skills to do with that (Darcy, Contextual Interview, lines 103-112).

In addition to working with the veteran teachers in the building, Darcy also works with the new teachers. She explained that during the current school year, the mentors of the new teachers arranged for them to observe Darcy's classroom. Darcy felt "that's a good compliment, …that they want to come see me teach and they respect me enough that they're not...I'm not gonna show some ridiculous thing up there (Darcy, Contextual Interview, lines 115-116).

The shift in the philosophy of the Baskerville Middle School math department has led the staff to reconsider the curriculum used in the school. Over the last four years, the teachers have used selected units from the reform-oriented curriculum, Connected Mathematics, or CMP (Lappan et al, 1998); beginning next school year, they will fully implement Connected Mathematics 2 (Darcy, Contextual Interview; Michelle, Contextual Interview). Darcy feels that the youth of the staff (i.e., all but one teacher has less than ten years of teaching experience) has created this "new flare of willingness to try the new curriculums" (Darcy, Contextual Interview, line 27). Keith also viewed the youth of the staff as contributing to the general philosophy of the department. He stated that, "since most of the teachers are a little bit younger they have a more modern education so they're more into using activities and tasks rather than just lecturing all day (Keith, General Interview #1, line 18). Nicole also discussed the assistant chair of the mathematics department's role in the changes in the department, particularly regarding the adoption of CMP. The assistant chair participated in ESP with Darcy, and according to Nicole, "she has been a proponent of Connected Math and has tried to help move things along," further noting that she deserves "some of the credit for the…changes that have happened" (Nicole, Contextual Interview, lines 44-45).

Michelle described the department as being "as unified as it can get", given that there is a staff of 14 math teachers (Michelle, Contextual Interview, line 19). Darcy noted that this shift in beliefs about teaching and learning was slow to take hold, but that through opportunities such as peer observations and departmental meetings, the staff has been working towards a cohesive approach. Nicole also discussed how one teacher at the school with whom she has worked "has come full circle" from being "adamantly opposed" to the use of reform-oriented curricula to embracing the underlying principles and implementing them in the classroom (Nicole, Contextual Interview, line 47).

Interestingly, though, the algebra course primarily used a traditional textbook for the current school year, with the exception of one unit from CMP that focused on linear functions. Darcy explained that this was a compromise between the middle school and high school.

> We've been told to use a very standard book, the Prentice Hall, which is, … in my eyes, a little step up of Dolciani....at the middle school here, we wanted Core Plus which is like a connected math but for high school level kids, ...we're in a battle with the high school and it just...you came down to, 'Well, this will satisfy everybody, we'll just throw in some Connected Math activities (Darcy, Contextual Interview, line43).

Keith uses CMP in the 6th and 7th grade classes he teaches. He describes CMP as "all open-ended…. for the most part, it's exploratory learning" (Keith , General Interview #2, line 318). Keith views the Prentice Hall text as "more traditional. It tells you how to do something and then gives you a bunch of examples" (Keith, General Interview #1.1, 153-154). For Keith, this contrast between the mathematics of the two curricula creates a different understanding among the students. He stated that, "Prentice Hall is easier but I think that they get a better understanding from Connected Math" (Keith, General Interview #1.1, line 157). He clarified by describing his algebra students' understanding from the one CMP unit used in the class as compared to his own experiences from a textbook similar to the Prentice Hall:

> I've noticed that they tend to understand why things work in terms of slope whereas when I was in school I thought of slope as changing y over changing x, rise or run, y_2-y_1 over x_2-x_1…they understand that as a per unit rate of change (Keith, General Interview #1, line158).

Keith also discussed how the style of the Prentice Hall book is not in line with the valued teaching practices in the department. He stated that

> the way we kind of combat that is to pull out certain things that lends itself well to activities and we just assume the kids won't look ahead because kids usually don't if they don't have to and then we'll make it...make something into an activity where we take away some information or just create a larger problem for them to solve (Keith, General Interview #1, line 155)

Next school year, however, the algebra students will be given the Prentice Hall book to use at home as a reference, while a portion of the CMP2 books will serve as the core text in the classroom (Darcy, Contextual Interview).

4.3.2 Keith's Day

This section focuses on the typical structure of Keith's day at Baskerville Middle School. First, Keith's perception of time allocation during the school day is examined and then compared to the views his mentors and supervisor hold regarding his use of time during the school day. Next, Keith's instructional practices are explored, beginning with his lesson planning and then the enactment of the lessons in his focus class.

4.3.2.1 "No time" during the school day Baskerville Middle School "I wish I had more time for everything" (Keith, General Interview 1.2, line 107). From planning and enacting lessons to talking with other teachers and completing his university work, Keith repeatedly stated he felt pressured because of the lack of time during the day. This section further explores the notion of time constraints on Keith's day, from his perspective and that of his mentors and supervisor.

<u>4.3.2.1.1 Keith's perspective</u> One way Keith attempted to gain more time was to arrive 30 minutes before he was required. He typically arrived at school around 7:00 each morning. He used this hour before homebase began to make copies for the day, grade student work, clarify last minute details of the day's lessons with one or both of his mentors, and work on university coursework. For example, on day two of observations, Keith spent a few minutes completing an assignment for a class at the university that was due that evening. On day three, he spent most of the time entering student grades on the computer, noting that he "wished the middle school gave [interns] a laptop like they do at the high school so I could do my grades at home" (Fieldnotes, day 3, p.3). On day four, Keith spent the time reviewing information for the 6th grade lessons that he was teaching that day. Occasionally, this time prior to homebase was also used to tutor students. This occurred twice during the observations. Keith explained that "during the first quarter we had students who were struggling so we invited them to come in at 7:30 if they had trouble and one of them has continued to come in" (Keith, General Interview #2, line 393).

Although the extra time in the mornings has helped him some, he still expressed frustration at not having enough time during the day to talk to his mentors and other teachers. Throughout the day, Keith had very limited interactions with other teachers, which he attributed to being a function of his schedule. He emphasized that

> I teach five periods a day, I eat lunch for a period, I have a planning period and then one team meeting. So other than the team meeting,

> which you wouldn't have seen[10]...I mean, I actually interact with other subject teachers on our team. Other than that, I really don't get a chance to interact with other teachers because I really have one planning period during which I'm supposed to be planning and working with my mentor so, unless I were to stay after school...even if I did that, people don't really do anything after school anyway so, no, there's really no chance to interact with other teachers (Keith, General Interview #2, lines 137-139).

Keith also stated that the lack of available time during the day impacted his ability to plan lessons with his mentors. He said that with Michelle "there's supposed to be time during the day but there's not. There was just no time to sit down and plan a lesson cause I have one period a day and it often ends up being other stuff" (Keith, General Interview #1.1, lines 354-355). Michelle stated that they try to meet during their 4th period planning at least three times a week to discuss planning as well as reflecting on how things have been going in the classes. She noted that this is not always possible, though, because

> that planning time is also the same time that our sixth graders eat lunch which is...when someone wants to come in to get extra help the only time they can come in is during lunch then sometimes I have to give that time up to work with them (Michelle, Contextual Interview, line 182).

During the five days of observations, Keith and Michelle tutored students during the planning period on days two and three. They met together for approximately 20 minutes on days one and four, and 30 minutes on day five. On day one, the conversation focused on Keith's ideas for the new unit in 7th grade. He described his plans and Michelle provided some general feedback. For example, they discussed Keith's idea of combining two of the sections from the textbook.

> KN: I was going to combine 3.1 and 3.2. I think that the big idea is the same.
>
> MF: Did you talk to [the other math teachers]? They already did those sections.

[10] Because of school policy, I was not permitted to attend any of the team meetings.

KN: No
MF: It might be a good idea. They could give you ideas of what to keep or adjust (Fieldnotes, day 1, p. 24).

The conversation continued at the unit level, with Michelle pointing out how the topics connect to other subjects, grade levels, and what other 7th grade teachers have already taught. At the end of the conversation, Michelle noted that they are "not always this formal with planning" (Fieldnotes, day 1, p.26). On days four and five, the conversation involved some brief discussion of unit planning, but primarily focused on issues outside of planning, such as the logistics of Keith beginning to teach the 6th grade class.

Keith felt that he had "virtually no time to work with [Darcy]" because she is on a different team (Keith, General Interview 1.1, line 360). As a result their schedules do not coincide for a full planning period. Their schedules did, however, mesh so that they could talk for 10 minutes after the algebra class each day. Keith stated that

> basically if I want to plan with [Darcy], I have to stay there after class and miss my lunch to plan with her. And it's usually not planning an individual lesson. It's usually just kind of the scope. Like I'm going to do this today, this tomorrow, do you have any suggestions...stuff like that (Keith, General Interview #2, lines 113-116).

Keith and Darcy did talk after class for each day of observations. Two of the five days of observation -- days one and four -- were spent discussing some component of the upcoming lesson. For example, after the students left the classroom on day one, Keith asked Darcy about the ordering of lessons involving multiplication of polynomials and algebra tiles, which were the lessons for days four and five. Darcy suggested that he use the algebra tiles first as a way to build students' understanding of the procedure. Keith took a set of algebra tiles from the classroom so that he could plan at home (fieldnotes, day 1, p.31). After class on day four, they discussed how to proceed the next day given where the current lesson ended. Darcy suggested how to use a warm-up activity to connect the two lessons. After class on days two, three, and five, Darcy and Keith reflected on the enactment of the day's lesson. These will be explored in detail in section 4.3.3.1, which focuses on the feedback that Keith received about his instructional practices.

The only time Darcy and Keith had a full class period for planning was on day two while the students took the unit test. During this time, they both sat in the back of the room to plan lessons for days four and five, during which the students would be using algebra tiles. Algebra tiles are a set of manipulatives that are often used to model operations with polynomials. As shown in figure 10, there are three different sized tiles, each in two colors. The small square represents a 1 by 1 unit, or 1. The rectangular pieces represent x, and have the dimensions x by 1. The large square pieces have the dimensions of x by x, or x^2. The different colors are to denote positive and negative numbers, typically with yellow representing positive and red representing negative values.

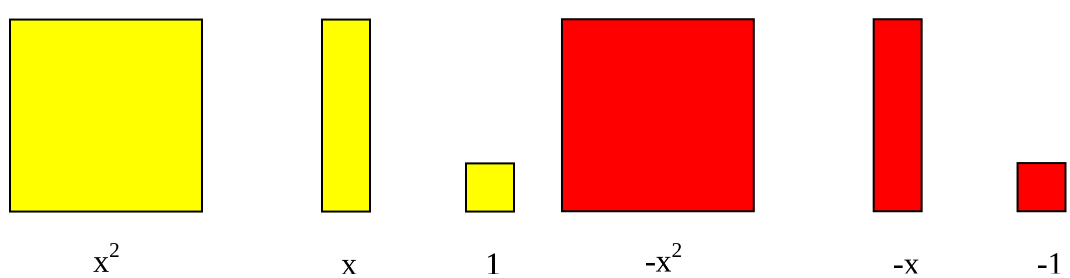


Figure 10. Algebra tiles

They both worked through some examples with the algebra tiles, with Darcy discussing how she has taught the lesson in the past, identifying problems she has seen students encounter, highlighting important mathematical points that should be made during the lesson, and suggesting ways of launching the problem as well as specific questions Keith may want to ask to elicit the key mathematical ideas of the lesson. As they progressed through the tasks, Keith asked clarifying questions both about the mathematics and ways to structure the lesson.

<u>4.3.2.1.2 The mentors' and supervisor's perspective</u> Keith's mentors and supervisor also saw him struggling with time management issues. However, they viewed the problem slightly differently than Keith. For example, Michelle felt that while time was a factor in his limited interactions with other teachers, part of it was also a lack of initiative on Keith's part. She explained that each day during 3rd period Keith met with all of the teachers on the 7th grade team. She described his participation as similar to that in the department meetings- attending but not participating.

> I don't think [Keith has] much of a participatory role...just...he's in there....On a daily basis there's usually some kids names that come up whether it's behavioral concerns or academic concerns and if it's a student that he has on a daily basis, he usually...he'll put his input in but for the most part is just kind of there (Michelle, Contextual Interview, line 74).

While they each recognized Keith's demanding schedule, the notion of him not taking initiative was the larger issue for his mentors and supervisor. Darcy, Michelle, and Nicole each independently stated that they expected a higher quality of work from Keith than he was producing. Michelle, having been an intern herself at the university, stated

> I was empathetic to the time constraints and the demands on course work versus teaching...but I also know what I did and how much time I put into it so I also know... what kind of sacrifices it takes to do your best at all of those things that you're being asked to do....I

> knew what it took and I knew that he wasn't doing that (Michelle, Contextual Interview, lines 336-338).

Nicole stated that if Keith was not constantly pushed,

> he's likely to sort of do the minimum that's needed to be done. And I think it's a function of how much there is to do, given the responsibilities of being student and an intern. And whatever else is going on in his life. (Nicole, Contextual Interview, line 97-100).

Darcy also described Keith as "completely stressed", noting that from her interactions with him he seems to be "always just getting...just getting to the next day,…the next minute, actually" (Darcy, Contextual Interview, lines 380, 382). For example, she discussed how as he took on more responsibilities, he was not using his observation time in her classroom effectively.

> I feel like after he started then being responsible to take on the actual classroom activities upstairs [in Michelle's classroom], then it was like he was feeling pressure to get that done so … instead of focusing on…. really trying to concentrate on questioning techniques or whatever, he's back there trying to rush, I guess to get prepared (Darcy, Contextual Interview, line 206).

One point that everyone, including Keith, agreed on was that his lack of time management primarily impact his lesson planning. Keith reflected that

> I was struggling to balance graduate school with teaching and I was kind of using the weekends to do my graduate school homework and trying to plan through the next class at night and it wasn't working out well. I was doing my lessons on notebook paper and I was forgetting things. And they weren't that insightful...the lessons....they just weren't going that well. So I would say just the overall expectation of having a good, clean,...well-flowing lesson...wasn't being met. And the way ...we remedied that was we laid out a plan of how I would … prepare in the future. I would do everything I had to do on the weekends and that way I could use the nights to adjust things rather than coming home after fifteen hours, trying to think of something creative then. Cause it wasn't happening (General Interview 1.1, lines 267-274).

The next section further explores the mentors' and supervisor's general views on his lesson planning. Then Keith's planned lessons for the five days of observation in the focus class, particularly the cognitive demands of the task in the curriculum and lesson plan, are examined.

4.3.2.2 Planning lessons Darcy, Michelle, and Nicole each indicated that the enactment of lessons was not always effective because, from their point of view, Keith did not always fully think through various aspects of the lesson prior to enactment. Darcy stated that when planning a lesson, "you have to study...the lesson in and out. How you're going to orchestrate it. Otherwise,...it could be a flop" (Darcy, Contextual Interview, line 278-280). She said that she often felt Keith did not have a clear "vision where [he] wanted to end up" at the conclusion of a lesson or how to tie lessons together (line 408). Similarly, Nicole distinguished between just having a written lesson plan and the quality of the content of the plan. Regarding Keith's written plans, she stated,

> I don't think he was planning carefully enough. And it's not that he didn't have a lesson plan that had questions and whatever imbedded in it...I didn't think he was thinking enough about particularly the launching of the problem....so that may seem sort of trivial but it seemed to me that a lot of times his inability to launch the problem well impacted the rest of the lesson…. he doesn't really try to think about how to connect the children's lives and prior mathematical experiences with the math topic of the day in the way that is really productive (Nicole, Contextual Interview, lines 112-115, 131).

To illustrate her point, she discussed specific instances of how Keith's lack of planning for the set-up of the task impacted the enactment of the lesson. For example, during one of her observations in the Algebra class, Keith was teaching a lesson from CMP on slope that uses staircases as a way to think about rise and run. She noted that in setting up the lesson, Keith

> did ask some general questions about [staircases]... but almost because you were supposed to. Not that he had a targeted...notion of what he wanted to come out of the questions which was going to

> help him deal with the mathematics of the lesson (Nicole, Contextual Interview, lines 119-120).

Darcy also talked about this particular lesson as an example of Keith's lack of initiative and thoughtfulness with planning. She recalled how the day before this lesson the two of them discussed for over 40 minutes a variety of ways to launch the task. She left the final decision of how to orchestrate the set-up to Keith. She expressed her disappointment in the final plan and enactment of the set-up.

> We spent all that time coming up with things to talk about and nothing was brought up….How disappointing….and it ended up being not a bad lesson but it could have been a lot stronger (Darcy, Contextual Interview, lines 348, 350- 351).

Keith recognized he wasn't doing a good job with planning during the first few months of his internship. He described his vision of a "good lesson" as

> one where the lesson runs smoothly,... fits into the time that you expect it to, the students get out of the lesson what you expect them to,...they participate. And I wasn't putting all those things together very well. And part of that was I wasn't planning very well. I mean I still struggle with that sometimes but I would say I wasn't putting enough time into planning (Keith, General Interview #2, lines 92-95).

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Keith stated he began to change his planning practices after conversations with his mentors and supervisor following the lesson on slope, noting that Nicole "was kind of a catalyst for what to do to improve in the algebra class" (Keith, General Interview 1.1, line 324). He said that Darcy then helped him focus on planning specific pedagogical moves, such as orchestrating discussions. "Rather than just putting content in my lesson plans we were focusing on putting transition things in there" (Keith, General Interview #2, line 120). Appendix K provides an example of Keith's current lesson plan format. He noted that now he spends "a lot more time planning. I plan out in pretty much...in pretty good detail what I want to happen" (line 145).

When planning the details of a particular unit or lesson, the teachers at Baskerville Middle School have the flexibility to use the curriculum "as is" or to make modifications as they see fit for their individual classes. Michelle explained that while there is a "common assessment pressure" to cover the same topics, the teachers still have freedom to make decisions about when and how topics are discussed (Michelle, Contextual Interview, line 76). According to Darcy,

> we have our scope and that's what we follow….Everybody realizes what chapters we need to cover, what books we need to go through....There's no time line, as far as….do this in a day...we're not real that specific (Contextual Interview, lines 151-152).

Keith understood that while there was a basic guideline, he also had the opportunity to make his own decisions. He explained that

> obviously there are some strict expectations with regard to like curriculum. I mean, I can't just decide to teach something that's not in the curriculum or I can't decide not to teach something that is. But I feel like I have the freedom to write my lessons however I want, to do whatever activities I want (Keith, General Interview #2, lines 204-206).

Interestingly, though, he also stated that he relies heavily on the teaching suggestions in the CMP texts. He elaborated, saying

> I feel that it would be foolish of me not to use resources that are provided by a group of people who have a lot more experience in education than I do. I feel that the inefficient use of my time to completely plan when a good template is provided for me and, plus, seeing how it's my first year of teaching, I don't have the greater understanding of how it works in with the whole year, whereas they do. They know what comes after what and like every little detail that's gonna be in every future investigation whereas I don't (Keith, General Interview #1.1, lines 201-203).

He acknowledged that there were a few select times when he elaborated on a topic more than the CMP materials did. For example, he discussed how after finishing an algebra unit in the 7th grade, he took the opportunity to further discuss the distributive property. He felt that during the unit, the concept was available to the students informally, particularly through a few homework problems, "but you had to, as a teacher, recognize that. So in that sense, I decide what to highlight that's maybe not explicitly obvious" (Keith, General Interview 1.1, line 435-436). He emphasized, though, that he did not do this often since the CMP materials

> kind of tell you what's important…. the main ideas so,…I just follow the book and if there's something that I feel is important that's not in there I try to bring that out (Keith, General Interview #1.1, lines 430-431).

Keith does not, however, find the suggestions from the Prentice Hall teacher's edition very useful, noting that the suggestions are not as extensive as those in the CMP materials. As a result, he says that "I do what I can with the Prentice Hall" (Keith, General Interview #1.1, line 535).

The influence of CMP is visible not only in the CMP classes, but in Keith's algebra class as well. He discussed how he used the CMP lesson plan format of "launch, explore, summarize" to also plan lessons in the algebra class. Three of his written lesson plans in the focus class (days one, four, and five) did explicitly have those section titles; the written lesson plan Keith provided for day three was the worksheet he distributed to the students. He stated he used the CMP format while planning lessons for the algebra class primarily because of his comfort level with the format. He explained

> that's what I've been taught, that's how I've been teaching all year. That's the way CMP presents their lessons....plus, I mean, it follows my education at [the university]....let the students make some sort of

> discovery and then talk about it as a class (Keith, General Interview #2, lines 526-529).

Darcy also encouraged Keith to "CMP it" when planning lessons for the algebra class. She explained that this is a phrase she uses often with Keith and other algebra teachers as a way to describe modifying the traditional lessons from the Prentice Hall book.

> you could probably just take, if it's like lesson 3.5 in the Prentice Hall book … maybe do a launch activity would be similar to Connected Math and then just go through your traditional examples. Some how do something that is kind of CMP type and work it into your lesson that way and not have to...reinvent the whole wheel, but try to...try to put parts of it into it (Darcy, Contextual Interview, lines 44-45).

For example, on day three of observations following a lesson that both Darcy and Keith felt did not go well, Keith mentioned that he was not as comfortable teaching in a "guided lecture" style. Darcy reminded him that he could make any of the lessons "CMP oriented". She then proceeded to provide specific examples of how he could have used group work for the lesson and specific questions he could have asked that would have opened the dialogue between the students about the mathematics (fieldnotes, day 3, p.20-21).

Keith indicated that he understood what Darcy meant by the phrase "CMP it". He explained it as "introducing less and letting [students] figure out more and then talking about it afterwards rather than showing them how to do everything and then giving them examples to work on (Keith, General Interview #2, line 491). However, Darcy stated that she believed Keith was tied to the curriculum, which she did not view as a positive characteristic. She described the Prentice Hall book as "horrible" and so she told Keith "from day one you can flex from it, whatever you wanna do…and that's one thing that I have not really seen" from Keith (Darcy, Contextual Interview, lines 164, 167-168). A comparison of the tasks in the curriculum and Keith's planned tasks for the four days of lessons (day two was a test, so no lesson was planned for or enacted on that day) do indicate that Keith did primarily rely on the textbook for tasks; however he did find an alternative task for one lesson and adapted the tasks in the textbook to increase the cognitive demands of the planned lesson on days four and five (see table 13).

Day: topic	curriculum	IQA rating of source	Keith's Planned task	Relation to source of task
1: Daniel Webster and the Devil task	Prentice Hall Textbook (section 8.7)	2	4	Invented- demands increased
2: test- KN and DD plan algebra tiles lessons	No instructional task	No instructional task	No instruction al task	No instructional task
3: polynomials - defining and adding- whole class discussion	Prentice Hall Textbook (section 9.1)	2	2	Adapted- demands maintained
4: algebra tiles to find the product of a monomial and binomial	Prentice Hall Textbook (section 9.2)	2	4	Adapted- demands increased
5: using algebra tiles to introduce factoring	Prentice Hall Textbook (section 9.2)	2	4	Adapted- demands increased
Average Score on IQA		**2.0**	**3.5**	

Table 13: Summary of the IQA score for the original and planned task

On day one, Keith used the task Daniel Webster and the Devil (see Appendix L) to supplement the ideas raised in section 8.7 of the Prentice Hall book. This task was coded as invented since he utilized a task from outside of the curriculum. Prior to observations, the class had completed a unit on exponents. He thought the unit had been "fairly devoid of activities" (Keith, General Interview #2, line 55). He wanted to provide the students with a problem that was not “strictly procedural”, so he “found [a task] on the internet” that he felt aligned with the ideas section 8.7 of the book (Keith, General Interview 1.2, line 56). In using this task, he increased the cognitive demands of the task from the textbook from a two on the IQA to a four for the planned task (see table 13). The original lesson focused students’ attention on evaluating a given exponential function by creating a table of values and then graphing that function. Four examples were provided in the text as a guideline for solving additional problems. In contrast, the task Keith planned- Daniel Webster and the Devil- provided students with the opportunity to solve a problem in which the answer was not obvious or the focus. The task began with a contextual problem that asks students to analyze a proposed payment plan and decide if Daniel should accept the deal. While the task did explicitly prompt the students to create a table, the purpose of the table was to identify patterns and make generalizations. In addition, the task asked the students to predict the type of graphs that the salary and commission data would generate.

For the remaining three lessons, Keith used the tasks from the book but made some adjustments to them. As a result, each planned task was coded as adapted. On day three, he created a worksheet to hand out to the students that was a slightly modified version of the information and examples from the book. For example, question one in the textbook provided three expressions and asked students to examine the given table and select the one that corresponded to a particular customer’s order, which was the context of the problem. Keith simply removed the choices, asking students to write the expression. Additionally, the textbook defined various words, such as “monomial”. While the worksheet Keith created also had the definition, he left a blank space for the students to write in the new vocabulary words. When asked about the worksheet, he stated that he

> based them on the way [Darcy] does a class. She usually gives them a worksheet with blank spaces like where vocab words go and then...she'll introduce something and give examples and have them work along with her. Um...basically I figured out she just basically takes them out of the lesson section of the book, like, and she basically follows the same order that the book does so I did the same thing (Keith, General Interview #2, lines 498-500).

These changes, however, did not change the cognitive demands of the lesson. Both the task in the curriculum and Keith's planned task focused students' attention on three topics: 1) memorizing definitions, 2) classifying polynomials based on the stated procedure of writing the polynomials in standard form, placing the terms in order, combining like terms, and naming the polynomial by its degree, and 3) adding and subtracting polynomials by combining like terms. Overall, the task did not require students to explain their reasoning or make connections between representations or to the underlying mathematical concepts; therefore, as table 13 illustrates, both the task in the curriculum and the planned task were scored as a two on the IQA.

The lessons on days four and five were also adapted; however, these adaptations led to the increase in cognitive demands. The focus of these two days was on multiplying polynomials by monomials and factoring monomials from polynomials. The task as it appeared in section 9.2 of the textbook was coded as a 2 on the IQA (see table 13) because the worked out examples in the book provided explicit procedures that were to be used on the subsequent practice problems and the focus was on producing the correct answer rather than understanding the underlying mathematical concepts. This was evidenced by the relationship between the examples and practice problems. Example one showed students how to multiply a monomial and a trinomial by following the steps of "use the distributive property, multiply the coefficients and add the exponents of powers with the same base, simplify" (Prentice Hall, p.462). Three problems were the given for students to practice and "check understanding". Following additional examples on finding the greatest common factor and factoring out a monomial (each of which were outlined similarly to example one), the exercises (i.e., 44 practice problems associated with section 9.2) referred students back to the corresponding example for each block of problems; that is, problems 1-12 referred students to example one, since the problems were analogous.

Keith, however, modified the lesson from the textbook. His adaptations of the material in the textbook increased the cognitive demands of the lesson and scored a four on the IQA. As previously discussed in section 4.3.2.1.1, during a planning session on day two Darcy recommended that Keith consider using algebra tiles for the lessons on days four and five as a way to introduce the concepts of the lesson to the students. He utilized that suggestion as well as the suggestion of how to design the worksheet. For example, Darcy had suggested that he may want to create "a sample sheet that has…maybe four basic ones you wanna multiply (Transcript of focus class, day 2, line 94), which is exactly how Keith structured the worksheet. Appendix N includes a copy of the worksheet Keith distributed in class on days four and five. His planned task involved using the algebra tiles to model multiplication of a monomial and binomial, finding the greatest common factor, and factoring out a monomial. There was an explicit procedure to follow in using the tiles, but the procedure was directly connected to the underlying mathematical concepts of the lesson. The task prompted students to make explicit connections between the given expressions and manipulative representations, as well as the area model of multiplication. This task was planned as a two day activity. Keith stated that he wanted to use the algebra tiles as a way to give students "a concrete thing to work with….just to kind of help them understand why things work" (Keith, General Interview #2, lines 541-542). The textbook suggests the use of algebra tiles with the following section, 9.3, but Keith wanted to use them with section 9.2 in order to

> create the meaning before we create the procedure….That's kind of following along the idea of CMP…. rather than telling them how to do something, let them kind of experiment with it a little bit to try to figure out what's happening (Keith, General Interview #2, lines 555, 557-558).

4.3.2.3 Enacting lessons Keith's mathematical goals for the series of lessons in the focus class are summarized in table 14. Keith consistently maintained the cognitive demands of his planned task both during the set-up and enactment of his lessons (see table 15). While the IQA score for the set-up was always the same as the planned task, twice (days 3 and 5), the enactment of the lesson received a lower score, even though the overall cognitive demands of the lesson remained the same. Day three was the only day that Keith planned for and enacted a low-level task. His average set-up score for tasks was 3.5; the average score for the enactment was slightly lower, a 3.0. This section further examines each of the tasks as set-up and as enacted in the focus class. Specifically, the cognitive demands of the tasks, the questions, and the representations available and used in the lesson will be explored.

Day	Goal
1	I'm just interested in them realizing that salaries are going to go up then down, the commission is going to go up. Just kind of develop a little intuition about exponents and that's...even though we're...even though we're not officially covering exponential functions, we're just doing the operations of the properties of exponents, I'm just trying to develop a little intuition with exponential functions (General Interview 1.1 lines 71-79). We're basically working on applications of some of the stuff they've...application of some of the properties they've learned….So basically I want them to...it's a little tricky to figure out exactly what the next day's salary is so, I mean, that's just kind of a working through the problem, that really doesn't have anything to do with the mathematics behind it but once they get the worksheet started, once they get the pattern right I'm just looking for them to be able to generalize the...commission based on the number of days.
2	(students taking test)
3	Today we're going to start a new chapter. It's polynomials. We're gonna introduce adding and subtracting polynomials which we really already know how to do. And just gonna get some vocabulary down like monomial, binomial, stuff like that.
4	We're going to use algebra tiles to um...simulate multiplying monomials and binomials. Um...finding the greatest common factor with algebra tiles and factoring.
5	KN: Well, today we are going to finish up the lesson from Friday which is using algebra tiles to find the greatest common factors and how to (xxxxxx) factor. And if we have time, we're gonna get to a...how to do that with things that we can't model with tiles. JM: What do you mean? KN: Like, we can only model...um, well we're doing (xx) with monomial and binomial and we can only model things that we can fit onto the page with the algebra tiles. We're gonna try to like get a concrete um...way of um...multiplying for any number. (xxxxx) model how we find the greatest common factor of any number, (xxxxxxx) factor anything. Any...well, anything that would be created by a monomial and a binomial. JM: Okay. Anything else? KN: Other than just kind of relating it to like the area of...like the algebra tiles kind of create like a...like a rectangle with dimensions and an area, I guess just relating the answers to that.

Table 14: Keith's goals for each day, as given in the Lesson Centered Interview unless otherwise noted

Day: topic	original	planned	set-up	enacted
1: Daniel Webster and the Devil task	2	4	4	4
2: test- KN and DD plan algebra tiles lessons	No instructional task	No instructional task	No instructional task	No instructional task
3: polynomials - defining and adding- whole class discussion	2	2	2	1
4: algebra tiles to find the product of a monomial and binomial	2	4	4	4
5: using algebra tiles to introduce factoring	2	4	4	3
Average Score on IQA	**2.0**	**3.5**	**3.5**	**3.0**

Table 15: Summary of the IQA score for the original task, planned task, set-up, and enactment of the task in Keith Nichols' classroom.

<u>4.3.2.3.1 Day One: high-level of cognitive demand</u> Keith launched the task on day one by having students predict if, based only on their understanding of the context, Daniel Webster should accept the payment plan proposed to him by the devil. After discussing the predictions, Keith clarifies the directions for the task and students begin to work in small groups. The task was set-up and enacted in a way that maintained the cognitive demands from the lesson plan, thus scoring a 4 on the IQA. The task for this lesson can be found in appendix L. During the 20 minutes the students spent working on the task at their tables, Keith circulated throughout the room clarifying directions and asking students questions to both clarify their thinking and encourage them to further analyze the mathematics by looking for patterns.

Approximately 30 minutes into the class, Keith pulled the class together for a whole group discussion. A student shared how she completed the table for the salary and commission. From there, the conversation focused on the generalization $100(2^x)$ that a student suggested for the commission. The class realized that while the expression does not produce the correct value for the given day, it does produce the correct value for the following day. For example, as illustrated in figure 11, the generalization $100(2^x)$ yields a value of $200 for day one, which is actually the proper value to day two; similarly, the value obtained by $100(2^x)$ for day two is the true solution for day three's commission.

Number of Day	Correct commission	Value obtained by expression $100(2^x)$
1	$100	$200
2	$200	$400
3	$400	$800
4	$800	$1600
5	$1600	$3200

Figure 11. Table of values produced by a student for the task

Two other students suggested possible ways to adjust the formula so that the correct commission occurred on the correct day. The following conversation ensued:

KN:	So it's...like you said, you're one ahead.
Male St:	So maybe...100 times...
KN:	So how could we slow that down by? It looks like...for day number one we really had the value for day number two.
Female St:	You need a half. You need a half. Or something.
KN:	That's another idea.
Female St:	Maybe 100 times 1.5? Yeah...that would...

KN:	Okay. So we've got two different ideas here. One, [male student] said his numbers are one spot ahead of where they should be. [Female student's] idea was that we just have double the amount that we should.
St:	Um...maybe it should be 100 times 2 x minus 1. Two the 2nd power minus one.
KN:	100 times 2 to x minus 1. Okay. How's that...how's that gonna work? (Focus class transcript, day 1, lines 613-633)

The conversation continued for approximately 2 minutes, with the students evaluating the expression for the given values. The students then agreed that the revised version, $100(2^{x-1})$, does in fact work as a way to generalize the commission. Keith then directed the conversation back to the second idea of how to revise $100(2^{x})$.

KN:	[Female student], I'm also interested in your idea.
Female St:	I don't know. I just guessed on that.
KN:	You noticed that we had twice as much as we needed to.
St:	Yeah.
KN:	How could we build off of that?
St:	You'd have to use a graph to show that.
St:	So 100 times like...
St:	Couldn't you use a fraction?
KN:	Sure.
Female St:	But I don't know how to do that. I just guessed.
KN:	Okay. Take a minute...um...[male student] came up with a good way to, um, fix this. [Female student's] way is also good, though. [She] said the amount we're getting is twice as much as it should be. How can I keep this same form that we had before...
St:	How would you do the half?
KN:	Something times 2 to the x. [Male student #2], what do you think?
Male St #2:	I didn't (inaudible).
KN:	What did you come up with?
Male St #2:	I got 50 times 2 to the x power.
KN:	Okay, so [male student #2] came up with 50

> times 2 to the x. Would you like to show us
> how you came up with that?

The student proceeded to the overhead in the front of the room and showed how he used the graphing calculator to determine the equation; however, Keith did not connect the new equation to the female student's notion of having twice as much as needed. The last three minutes of instructional time were spent having students predict which type of graph they think would represent the salary data. After the students agree on the shape of the graph, Keith states that it is called a quadratic, and noted that "quadratics aren't anything that you're supposed to have known yet, I just thought it would be interesting to take a look at it" (Focus class transcript, day 1, line 767).

Throughout the lesson, there were 10 conversations in which connections were made between representations. In each of these instances, the connections were prompted by Keith's questioning and it was the students who made the connection. The students had access to the context and table on the worksheet. The table served as a way to organize the mathematics based on the information in the context, and was used as the jumping off point during the class discussion. Keith began the discussion by asking students how they could use the table to come to a conclusion. One student responded

> you see how the…commission is gradually going up and, like, after a certain time you can see that it's not a good idea anymore to work for him…At 11, you'd be in debt because the commission is $102,400 and you don't have any money. And...so you can see how it goes up, like how this...your salary goes up and, well, goes down kind of because you get less and less, and then...you can see how…the commission is going up more and more (Keith, focus class transcript, day 1 lines 486-488).

Here the student is making a connection between the context and the table.

While the task did not explicitly prompt students to develop a generalized formula, Keith did so both as he walked around during group work and during the whole class discussion. Additionally, the table called for students to find the salary and commission for day thirty, thus implying the need for a generalization since the previous day on the table is 11. As previously mentioned, students also had access to three different equations, two of which were equivalent. While Keith did ask questions that connected to the mathematics for each equation, he did not make connections between the equations.

Language also played a large role in the class, and three of the connections conversations between representations involved language. For example, the students verbally described relationships between the day and the salary and the day and the commission. Additionally, students verbally described how the information in the table would be represented graphically. Keith drew sketches of their descriptions of graphs on the board at the end of the class.

During the lesson, Keith asked a total of 83 academic questions (see table 16). Keith began class by asking a combination of tuning and monitoring questions. Overall, approximately 60% of the questions asked throughout the course of the lesson served the purpose of monitoring students' understanding of the task and asking them to explain their thinking. For example, as Keith moved between groups while they solved the task, he often asked questions such as "How did you get those?", "What's that mean to you?" and "Is that going to work for day one?" (Keith, focus class transcript, day 1, lines 204, 435, 585). Nearly one-third of the questions asked during the lesson were connecting questions, with the majority (66%) of these occurring during the whole class discussion. During this time, Keith asked students to make use of and connections between tables, equations, and eventually graphs. For example, he began the discussion by asking the class, "So, how can you use Julie's table to make your decision?"

(Keith, focus class transcript, day 1, line 484). He also pushed students to further analyze the underlying mathematics and he prompted students to describe relationships between the days and the salary or commission.

Day: topic	Tuning	Monitoring	Connecting	Total
1: Daniel Webster and the Devil task	7[11] (8.4%)[12]	49 (59%)	27 (32.5%)	83

Table 16: Questions asked during the set-up and enactment in Keith's classroom on day 1

4.3.2.3.2 Day three[13]: low-level of cognitive demand Day three was the only day during observations that Keith planned for and enacted a task at a low-level of cognitive demand (see table 15). Keith closely followed the planned task, and as a result, the enacted lesson focused students' attention on memorizing definitions, identifying the degree of polynomials, and naming the monomial based on the degree.

Keith began the lesson by using the contextual problem and chart from the textbook (refer to appendix M for the task). However, confusion over the directions led to students calling out in a way that was disruptive to the enactment of the remainder of the lesson. At one point while giving the directions for the launching activity, Keith tried to explain how to read the chart. He stated

> if you see an x in say, Cassock's name under c, that means he bought a bag of seed. If you see an x under millet, that means he bought one millet (Keith, focus class transcript, lines 206-207).

Keith's explanation did not match the purpose of the task; that is, the "x" on the chart did not represent one, but rather an unknown amount. This error led to confusion and anxiety among the students. To settle the questions and concerns, Keith gathered the class together and told the

[11] Number of questions coded as such – ie. 7 questions out of 83 total coded on day 1 were tuning
[12] Percent of questions asked that day- ie., 8.4% of questions on day 1 were tuning
[13] Day two was a test. No instructional task was enacted so no data for Keith's instructional practices was collected during that day.

students what the expression would be for each person's order. Additionally, Keith did not use the problem in a meaningful way in the remainder of the lesson; that is the focus was on producing the correct expression, which involved one each of a monomial, binomial, and trinomial, rather than using the expressions as a means to further explore the new vocabulary. As a result of the focus on the writing the desired expression, the set-up of the lesson was scored as a 2 on the IQA rubric.

As the lesson progressed, the focus continued to move towards learning definitions. Keith repeated the textbook's definition of a monomial numerous times throughout the lesson. However, a few students continued to verbalize confusion about the distinction between monomials and polynomials. For example, approximately 40 minutes into the class, a student again questions the difference between polynomials and monomials. The following conversation ensues:

> St: So it has to have...for it to be a polynomial, it has to have some other form than multiplication in it.
>
> KN: What? Like I said, a polynomial is like a big family of which monomials is a part. So polynomials can monomials, they can be two monomials, they can be three...
>
> St: But it wouldn't be...this wouldn't be a polynomial, right? x squared y to the 3rd (xxxx).
>
> St: Yes it would.
>
> KN: All of...this is the polynomial family. Alright. This one...usually when decide what they are, we call them by their most restrictive form. So like, that top one, you could say it's a mono...polynomial but it's also a monomial. It's like...it's like am I gonna call you a human or a girl? I'm gonna call you by your most descriptive, most restrictive form. I'm gonna call you a girl. It's like when we have monomials and polynomials...I'm gonna call this a monomial. This...this bottom one is two monomials or one polynomial.
>
> St: Because they're added?
>
> KN: The fact that there's more than one of them makes it...so it cannot be a monomial any more. Mono means one. The fact

> that there's two of them makes it that...it cannot be a monomial any more.
>
> St: But how can you figure that top one is one and not two.
>
> KN: Because a monomial is one number, one variable, or the product of one number and a variable, or the product of two variables. *It just goes back to the definition of what is a monomial* (emphasis added) (Keith, focus class transcript, day 3, lines 738-769).
>
> .

This conversation was representative of the students' confusion and Keith's response throughout the lesson.

Beyond definitions, Keith also presented rules for finding the degree of polynomials and then asked students to use that procedure on example problems. For example, Keith described to the students how to find the degree of a polynomial by telling them:

> when we're looking at a polynomial and we wanna find the degree of the entire polynomial, we just look for the degree of the high...the highest degree of any of the monomials. So since we put them in standard form from like the greatest to the least...if we've already done that, we can just look at the degree of the leading one (Keith, focus class transcript, day 3, lines 668-669).

He proceeded to show an example, after which students worked on seven practice problems that asked students classify polynomials by finding the degree, naming the polynomial using the degree (e.g., quadratic), identifying the number of terms, and naming the polynomial using the number of terms (i.e., binomial). For example, on the last problem, $3x^4 – 4 – 2x^2 + 5x^4$, students combined the like terms and named the polynomial a fourth degree trinomial.

The planned lesson also involved students adding and subtracting polynomials; however, during the enactment Keith was only able to introduce one example at the end of class. The focus was on the procedure and obtaining the correct answer rather than on understanding the mathematical concepts that underlie the procedure. A student volunteered to do the problem on the board. After he completed the problem, Keith summarized his steps, saying:

> So the way [he] did it is one way. We can line them up and add them vertically. The only thing you have to be careful is you have to make sure you get like the right variables in the right columns. So like if there wasn't...let's say there hadn't been a -9x there, you'd have to make sure you didn't put the one here. You'd have to make sure you left a blank spot (Keith, focus class transcript, day 3, lines 1006-1009).

While students often expressed confusion during the lesson, the task was not challenging mathematically for the students, particularly as evidenced by the focus on definitions and the fact that the students already appeared to know how to add polynomials. Additionally, students were not pushed to engage in complex thinking or to understand or create meaning for any procedures. As a result, the implementation was scored as a 1 on the IQA, representing a low-level of cognitive demands focused on definitions and rules.

In addition to the lowest level of cognitive demand from any of his lessons, day three also represented the least number of questions asked and representations available to students. A context was available but in a generic way; that is, the task began with a chart that expressed customers' orders for bird supplies; however, the chart and context were used only to write expressions. There were no meaningful connections made during the lesson. In fact, Keith reflected that he wasn't even sure of why the context and chart was there until after the lesson.

Table 17 summarizes Keith's academic questions. Keith asked only 54 questions, which is 32 less than the average number asked per day. Of those questions, almost 80% were monitoring, and 17% connecting. This was also atypical of his questioning pattern. The few connecting questions either focused on connecting students' knowledge of language with the symbolic expressions (i.e., understanding that "mono" means one) or on prompting students extend their thinking. An example of this was when Keith asked, "Can you guys guess which monomial might not have a degree?" (Keith, focus class transcript, line 425).

Day: topic	Tuning	Monitoring	Connecting	Total
3: polynomials - defining and adding- whole class discussion	2 (3.7%)	43 (79.2%)	9 (16.7%)	54

Table 17: Questions asked during the set-up and enactment in Keith's classroom on day 3

4.3.2.3.3 Day four: high-level of cognitive demand The focus of class on day four was to use algebra tiles as a way to model multiplication of monomials and binomials. For example, figure 12 illustrates the correct model for (x+3)(2x). To begin, the appropriate pieces for each factor are placed on the outside of the mat, with one factor on the side and one on the top. For this particular problem, one yellow x piece (representing x) and three yellow units (representing +3) are on the side of the mat, while two yellow x pieces (thus, 2x) are placed on the top. The solution to the multiplication problem is obtained by filling in the area on the mat created by the dimensions, or the factors. To do this, the largest pieces possible are used first (ie., the x^2 block). The color of the piece placed in the solution is determined the signs of the corresponding factors (i.e., positive x times positive x is a positive $x^{2,}$). As shown in figure 12, the solution must occupy the full area encompassed by the factors. The solution can then be determined by counting the number of each piece in the solution area. For this particular problem, there are two x-squared pieces and six x pieces; therefore, the solution is $2x^2+6x$.

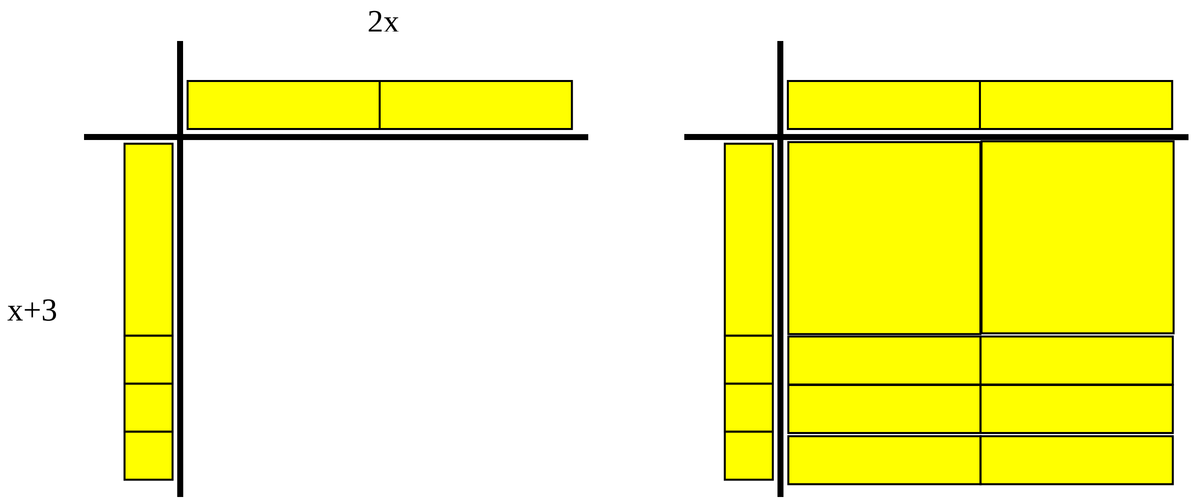


Figure 12. Using algebra tiles to model (x+3)(2x) and to determine the solution

Keith's lesson was both set-up and enacted at a high-level of cognitive demand, scoring a 4 on the IQA. While the lesson required that students use a specific procedure of modeling with algebra tiles, the purpose was to develop meaning for multiplying monomials and binomials.

Keith began class by drawing an "x by x" rectangle on the board, and asking two tuning questions.

> KN: What...what does the inside of this shape represent?
> St: Area.
> KN: Area. So how do you find the area of this shape? What do you end up doing?
> St: X times x.
> KN: X times x or...
> St: X squared.
> KN: Okay. So, when we have um...we would call each of these a product. So these are two things that we're gonna multiply together to get an inside value. So, if I had just given you x times x you could have come up with the same answer. But this is just like another way to express the answer in terms of like a geometric picture. So what we're saying is...we're saying this whole square represents x times x. We're going to be using that sort of idea today (Keith, focus class transcript, day 4, lines 28-46).

This opening dialogue connected to students' understanding of the area model of multiplication, which Keith then extended to multiplying monomials and binomials. He repeatedly referred back to the basic area model throughout the lesson to connect the procedure and mathematical concept.

Keith engaged the students in a four minute conversation about the value of each of the algebra tile pieces. During this time he emphasized that even though five units almost "fits" on one rod the value of the rod is "x". He also discussed how to use the different colors to model positive and negative numbers. These were two points that Darcy highlighted with Keith during the planning session on day 2 as potential places of student confusion.

Keith then asked students how to model the expression "x+3" using the tiles. He connected back to the drawing from the start of class, stating,

> What we're gonna do is...we're gonna create like out own little...our own shape like we have over here. We're gonna create our shape and like we did here...when we multiply them together we're basically creating an area. And our area is also our answer for our...for our um product. So what we're gonna do is we're gonna create our own shape here (Keith, focus class transcript, lines 133-136).

After the class agreed on how to model (x+3)(x) and find the area using the algebra tiles, Keith handed out a worksheet that had four problems for the students to solve. The students worked at their tables for approximately 10 minutes. During this time, Keith circulated, answering questions and clarifying directions.

Prior to beginning the class discussion, he asked four students to sketch their solutions on the board. He then directed students to "put your area into variables. You have it in terms of shapes right now. But our shapes represent something. So I want you to put your shapes into a formula" (Keith, focus class transcript, day 4, lines 659-662). After a few minutes passed, Keith asked for volunteers to share and explain their solutions. Prompted by a student's question on the first problem, he again linked back to the drawing from the beginning of class to clarify why the terms in the solution were added. Figure 13 shows the initial drawing and how Keith modified it during the following conversation.

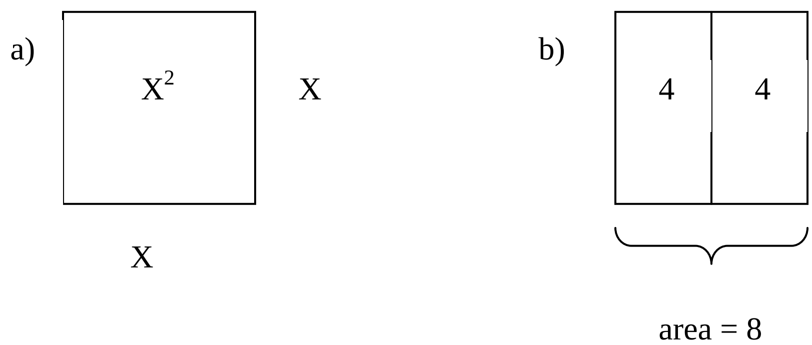


Figure 13. The first is a drawing on the board that Keith referred to as a means to create the second drawing

KN: So if I say....let's say I say the area of the whole thing is 8 (referring to figure 13a) and I said the area of this part is 4 and the area of this part is 4. What's the area of the whole thing (referring to figure 13b)?
ST: Uh..16.
ST: Eight.
KN: Eight. If the area of this part is four and the area of this part is four, the whole area is eight.
ST: Yeah, that's what I meant.
KN: So, over here (referring to the algebra tile pieces in the solution area of the mat) , I know the area of this part and this part and each of these individual parts so I can just add them up…do you agree that...now that this is +4 or do you still disagree (Keith, focus class transcripts, day 4, lines 772-780).

A student explained the second problem, indicating how the pieces from the area model connected to the symbols in the expression. For the third problem, the student simply stated the expression; Keith did not ask him to clarify further, but instead asked a series of questions that both summarized the day's activities and laid the groundwork for day five. Keith asked if it is possible to have a situation when the area portion of the algebra tile mat was not completely filled in; figure 14 provides an example to clarify what Keith was asking. After students stated that it would not model the multiplication properly since the area is not complete, Keith asked, "Do you think it's possible to find what goes on the outside just based on what's on the inside?" (Keith, focus class transcript, day 4, line 861). After a short discussion, students agreed that it could be done. Keith then introduced the term "factoring", stating that factoring and finding the greatest common factor would be the focus on the next day's lesson.

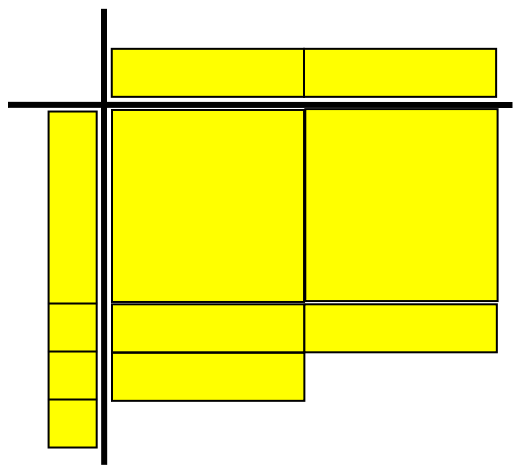


Figure 14. An example of an algebra tile mat that is not completely filled

Although the lesson did not involve many representations of a function, the manipulatives were used as a way to model a key mathematical concept – the area model of multiplication and how that model extends to multiplying monomials and binomials. There were numerous connections between the algebra tiles and the symbolic expressions. Specifically, a total of 35 separate conversations occurred where connections were made. Of those, 20 conversations occurred where the students made the connections, almost exclusively in linking the symbolic expression to the algebra tile pieces. For example, a student suggested that the answer to a problem was $-4x^2-4x$. Keith then asked the connecting question, “So, who can explain to me where she came up with that? How did she come up with negative 4x squared -4x?” (Keith, focus class transcript, day 4, lines 635-636). This question prompted students to express the connection between the manipulative representation and symbolic expression. A student responded, “there’s four of the…x squared blocks and 4 of the x’s” (Keith, focus class transcript, day 4, line 644).

The remaining 15 connections between representations occurred when Keith stated the connections. These took one of 2 forms- either Keith reiterating what a student had just said, or in clarifying directions, stating the connection. For example, after completing an example together with the students at the beginning of class, Keith reviewed the co-constructed solution as a means to review the directions for the group work.

> Each one is like it’s own separate part to the area. This is the part of the area determined by these two long pieces. These two parts are determined by the long piece with each unit (Keith, focus class transcript, day 4, lines 321-323).

In so doing, he stated the connections between the manipulatives and the symbols.

Table 18 outlines the types of questions Keith asked on day four. He asked a total of 99 questions during day four’s lesson. Only 2 of the questions were tuning, both of which occurred in the opening dialogue. He asked 60 monitoring questions. These questions encouraged students to explain their thinking (i.e., “So does anyone have a different idea?”, “Why is that?”) or aimed to have students produce the answer to a question (i.e., “So you have a negative and a positive, so what...is your answer going to be negative or positive?”) (Keith, focus class transcript, day 4, lines, 151, 272, 412). The remaining 37 questions were connecting. The connecting questions served to connect both between representations and to the underlying mathematical concepts, or to push students to further analyze the mathematics. The question that Keith asked at the end of class about factoring is an example of a connecting question from this lesson that prompted further reflection and analysis by the students.

Day: topic	Tuning	Monitoring	Connecting	Total
4: algebra tiles to find the product of 2 binomials	2 (2%)	60 (60.6%)	37 (37.4%)	99

Table 18: Questions asked during the set-up and enactment in Keith's classroom on day 4

4.3.2.3.4 Day five: high-level of cognitive demand The lesson on day five built on the previous lesson. Again, the students used algebra tiles as a way to investigate multiplication of monomials and binomials. Day five's lesson pushed that topic further by also exploring the ideas of factoring and identifying the greatest common factor. The set-up was scored as a 4 on the IQA; however, the implementation was scored as a 3. The rationale for each rating is further described below. The task can be found in appendix M.

The set-up of the main task for the day provided students with the opportunity to review the procedure for modeling multiplication with the algebra tiles, thus ensuring that the students would have access to the task of "working from the inside out". He began by asking a student to "recap what we did yesterday and what it was used for" (Keith, focus class transcript, day 5, line 31). The student described how the different color pieces represent positive and negative, and correctly told Keith how to model "-4x"; however, Keith took over at this point to describe how to model x(x+1) "geometrically". During the remaining 20 minutes of the set-up, Keith asked the students to explain how the pieces modeled the given multiplication sentence, asking questions such as, "How did...[she] break this up?" (line 189), "Is there a tile that could fit all the way down here and all in one?", and "Does anyone have any comments on the area?" (line 232).

This last question prompted a discussion on if the student's symbolic expression (x^4) matched the visual representation (2 x-squared pieces).

ST: Uh...I think x to the fourth is wrong.
KN: Okay. Why do you think that?
ST: Because x to the fourth isn't just like half. That's like...that's only two...it's only half the dimension (inaudible) cause if one square is x squared.
KN: Okay, so this...this is like x...let me write in black.
ST: And wouldn't that be 2x to the second?

Just as in day 4, Keith likened this to an area model with whole numbers. The conversation continued.

KN: Now if I gave you something that looked like this...if I said this area is four and this area is four, what's the total area there?
ST: Eight.
KN: Eight. So if we know...if we have a large figure and we know the areas of parts of it, do we wanna add or sub...add or multiply?
ST: Add.

Twenty minutes into class, Keith introduces the notion of greatest common factor through a series of tuning questions aimed at connecting to the students' understanding of the words "greatest" and "common". Keith again linked the process to whole numbers, discussing the factors of -9 and 3. After completing one example together, Keith instructed the students to complete the next four problems from the worksheets while he walked around.

Immediately, Keith went to the back of the room to talk with Darcy. During the set-up, he began to struggle with the model to show the greatest common factor. As a result, he was unsure of how to progress in the lesson. He drew on Darcy as a source of support during the lesson to provide some guidance.

KN: I'm having a hard time...I was having a hard time thinking about greatest common factor. I know how to find it, I have a hard time like saying why it makes sense.
DD: It's the one they share...they share the most.
KN: Yeah….

DD: The biggest thing is...you need to start with the original expression.
KN: Okay. The product.
DD: The product….You'd work your way back out.…To see where they came from. So you were trying to use one that they'd already worked the other way, so….you have to go back the other way.
KN: So one that they don't already know the answer to it.
DD: Right. Yeah (lines 437-456).

From this conversation and one that occurred a few more minutes into the lesson, it became apparent that Keith had not worked through each of the problems using the algebra tiles prior to the lesson. He was not fully prepared for some of the questions the students had regarding the use of the algebra tiles or how the tiles may model situations with a constant for the greatest common factor (ie., a greatest common factor of 5). Half of the problems (#2 and #4) had constants as the greatest common factors. As questions came up in class about how to model these, Keith instructed the students to not "spend too much time stressing on number two….Because it's something that we have to... extend how we're doing this to do number two" (lines 564, 566). Figure 15 depicts the algebra tile mat for problem #2, $-4x^2-4$. This problem cannot actually be modeled with tiles since, as Keith established at the end of class on day 4, the area does not make a rectangle.

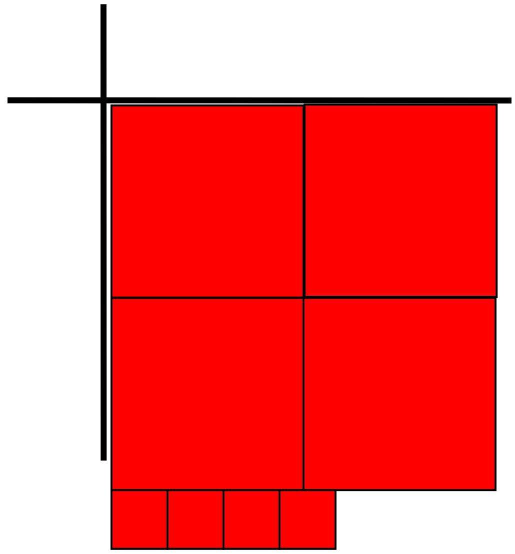


Figure 15. Model of $-4x^2-4$

As he worked with a group on problem #4, he again asked Darcy to come help him figure out how to use the tiles. After she worked with the group and was also unable to determine how to use the tiles to model the problem, Keith stated, “I’m thinking that these algebra tiles don’t work so well with...greatest common factors that are constants” (line 707).

Following this conversation, Keith gathers the class together for a discussion on numbers one and three. He then moved the conversation to discussing ‘factoring’, stating that

> whether you know it or not, you’ve...for the last like half hour you’ve been factoring. It’s like, when we wanna factor something, we wanna break it down into like what parts you multiplied together to get it (lines 882-883)
> .

While there were obvious difficulties with #2 and #4, Keith did conduct a discussion with the whole class that allowed students to work towards the goal of factoring polynomials. While students were able to state the greatest common factors for numbers two and four, they were not able to clearly provide evidence or explain their thinking. The struggles with this portion of the lesson led to a score of a 3 on the IQA.

The representations used in this lesson were manipulatives, symbols, and language. Similar to day 4, these were not representations of functions, but of a key mathematical idea. Of the 109 questions Keith asked during this lesson (see table 19), approximately half of the questions were connecting. This represented the highest percentage of connecting questions asked in any of the lessons. There were 12 conversations where students made the connections either between representations or to the underlying mathematical concepts. Keith also stated a large percentage of the connections, with 9 conversations of this nature. As in day four, though, these conversations often occurred as a clarification or summary of a student's explanation.

Day: topic	Tuning	Monitoring	Connecting	Total
5: using algebra tiles to introduce factoring	8 (7.3%)	47 (43.1%)	54 (49.5%)	109

Table 19: Questions asked during the set-up and enactment in Keith's classroom on day 5

4.3.3 Emerging issues from the analysis

Throughout the focus lessons and interviews, a few issues emerged regarding not only Keith's instructional practices, but the alignment of various aspects of his contextual settings. These issues, which are discussed in the following sections, were identified by reviewing the fieldnotes and interviews for common themes. The fieldnotes, transcripts of interviews, and focus classes were then coded for evidence of each theme. Three main issues emerged from that analysis: 1) the feedback Keith received regarding his progress, 2) his execution of that feedback, and 3) the consistency of the messages he received from numerous sources regarding both desired teaching practices and his work towards achieving those practices.

4.3.3.1 Receiving feedback on lessons Throughout the day, Keith received verbal feedback from both of his mentors on his enactment of lessons. This feedback ranged from conversations of less than a minute in between classes to a 10 minute discussion with Darcy following the algebra class on day three. While the length of time of the conversations varied, one aspect that was constant was the specificity of the feedback. This section further explores the discussions between Keith and his mentors on the days of observations.

While Keith and Michelle did not have formal conferences during the five days of observation, she provided Keith with some form of feedback each day. For example, the lessons on days one and two for the 7th graders focused on the role of the scale factor on perimeter and area between similar figures. After the lesson on day one, Keith noted that while he tried to let the students discover the relationship, he was not sure if they all understood. He revisited the topic on day two by using the previous night's homework as a way to discuss the topics. He decided at the end of first period not to assign any additional homework because he felt the students were still confused. In the 4 minutes between classes, he and Michelle debriefed the lesson. She provided feedback by using phrases such as "I'm wondering what would have happened if…." and "maybe try…". She also suggested that it "might not have been a bad idea to leave the homework, to let them struggle" (Keith, fieldnotes, day 2, p.11).

Keith stated that Michelle's feedback is always "very detailed" and "very insightful" (Keith, General Interview #1.1, lines 315, 317). He also appreciated the way she presented the feedback, clarifying that

> she's never said, "Well I do this or I do this"...I mean, she's always like, "Well, maybe you would think about doing something like this" or "At this point, you might have wanted to bring this topic up". She's never said, "This is how I do it". She's never given the impression that I should teach the way she does (Keith, General Interview #2, lines 196-198).

Darcy also provided explicit feedback after the focus class observations, with these conversations ranging from 5-10 minutes. The longest post-lesson feedback occurred on day three. As previously described, day three in the algebra class was the only day that classroom management was an issue, due in part to the organization of the lesson. It was also the most traditional style lesson that Keith taught in all the classes observed. Following the class, Keith and Darcy sat down and Keith immediately asked, "What should I have done differently? That was horrible." (Keith, fieldnotes, day 3, p.19). Darcy had made notes on the implementation of the lesson which she referred to during their conversation. She discussed the students' behavior, but linked it to the structure of the lesson and resulting confusion.

> DD: I don't think they know why the beginning part with the chart….You didn't know what you wanted at times.
> KN: I feel like I knew where I wanted to go….I was shocked at how much trouble they had with monomial.
> DD: Maybe you could have had them produce examples, then go back to the definition to judge (Keith, fieldnotes, day 3, p.20).

Keith expressed that he always has more trouble with a "guided class", to which Darcy continued to suggest specific ways Keith could have modified the textbook and lesson structure the class to make it more "CMP oriented". She ended the conference by giving Keith a "management point". She stated that when giving directions, "make sure everyone is with you." She then provided an example of how he might do this with the upcoming lesson with algebra tiles (Keith, fieldnotes, day 3, p.21).

Keith discussed how Darcy is "always willing to give feedback" (Keith, General Interview #1.1, line 298), stating that while sometimes she begins with a general comment such as "I think that went really well, or, that was a big improvement" (Keith, General Interview 1.1, lines line 296) she expands and

> doesn't give general blanket suggestions. She says, 'When so and so said this, maybe it would have been helpful to say this." Or like, "When so and so, when this happened maybe you could have brought this into the discussion." She's very specific about what she...how she thinks it could have been better and she's very specific about things that I did well (Keith, General Interview 1.1, lines 312-313).

Following the lesson on day four, Darcy did commend Keith on the lesson, noting that it was "much better today", pointing out that he did a good job introducing the tiles and the reasoning for the different color pieces to set up the lesson. Additionally, during their conversation on day five after class, Darcy noted specific places where Keith could have made other decisions. She focused on the one student who knew that the greatest common factor 5x+5 was five. She directed Keith's attention to sketches of possible solutions to the problem on the back board that she created during the lesson (see figure 16), noting specific questions he could have asked to elicit the key mathematical ideas.

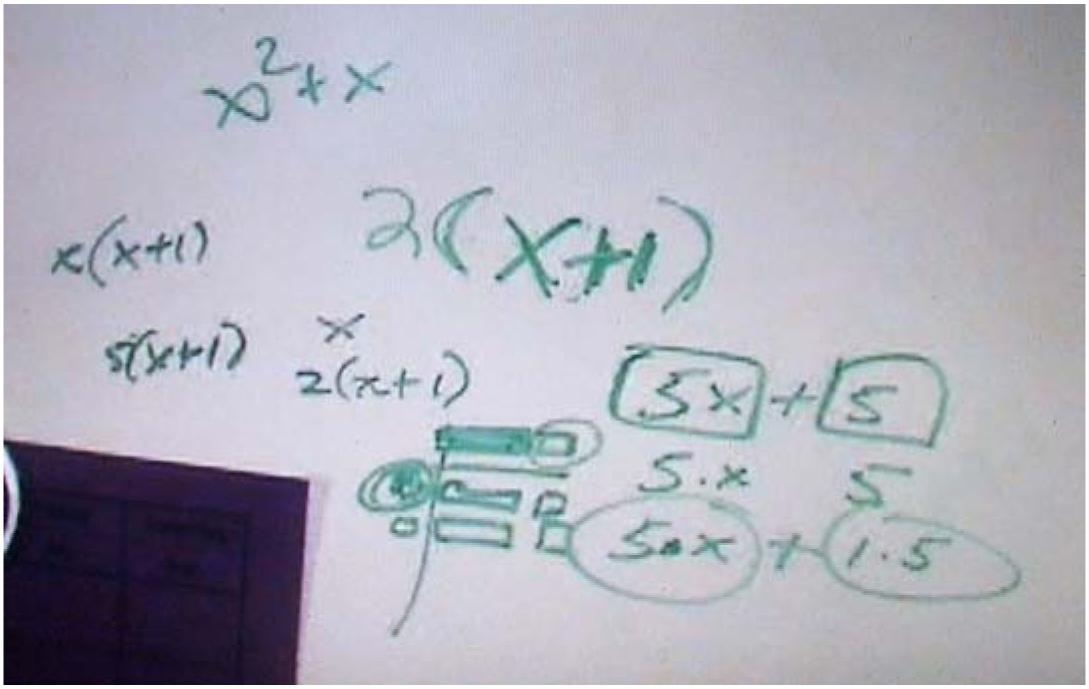


Figure 16. The drawing Darcy made on the board in the back of the classroom

The specificity of feedback also extends to Nicole. Nicole explained that her approach to supervision is

> to try to take notes on what's actually happening during the lesson and then try to identify with the teacher some area of instruction...which they feel they need to continue to work on. And then trying to use...the evidence collected during the lesson as a way to frame the discussion about whatever that particular thing is (Nicole, Contextual Interview, lines 76-77).

Keith explained that following lessons that Nicole observed, they have a post-lesson conference during which

> she gives very detailed feedback....I'm pretty good at like figuring out what I'm doing wrong, I'm just not...I've just always haven't been so good at fixing it. And like what I think is going wrong is usually the same thing she does so it's usually...and she sees the same things that [Michelle] does, so it's always aligned. Like we always have the same ideas. So, I mean, it's not like she's way over there and I'm thinking something else, so like it's helpful in that

> way.…she’s pretty tough though…. [she has] high expectations (Keith, General Interview #2, lines 272-277).

Both Darcy and Michelle also expressed that Nicole’s feedback is specific and influential on Keith’s practice. For example, Michelle felt that Nicole “gives him very good input, very good feedback. She does always try to be very specific… with reinforcing things and refining (Michelle, Contextual Interview, lines 304-305). Similar to his mentors’ feedback, Keith said he finds his conversations with Nicole beneficial to his teaching, noting that “wherever she is, she’s an influence on it” (Keith, General Interview #1.1, line 325).

4.3.3.2 Implementing the feedback Darcy, Michelle, and Nicole all agreed that Keith is able to almost always identify if and when a lesson went awry, but even with specific feedback the changes in practice were slow to take hold. Michelle stated that following a lesson

> he can tell you what went wrong and we can brainstorm things that are possible remedies but then to make changes those things haven’t been happening...even if I narrow it down to one specific thing... we’re just going to talk about x and we do that, and we talk about that and we say, “Okay, this is what we agree that this is what should be done to remedy x” then I might not see it in the next day’s lesson (Michelle, Contextual Interview, line 192).

Michelle further explained that from her point of view,

> he’s not much of a risk-taker...he’s very set in routines where...I tried to talk to him about changing just the variety of the way you do things in the classroom just to keep the kids...you know, keep interest a little bit better and nothing...that really hasn’t changed too much (Michelle, Contextual Interview, lines 375-376).

One common area of focus Keith’s mentors and supervisor stressed was planning and preparation. During the observations in the focus class, there were instances of his lack of planning for gathering materials for the lesson and lack of anticipation of student responses. On day one, Keith asked Darcy during class if there was on overhead projector for the graphing calculator available. This arose because a student was using the calculator to find the equation of the line, a method Keith did not anticipate. On day two, Keith had not planned an assignment for the students to work on after completing the test. After the first student turned in his test with almost 30 minutes left in class, Keith asked Darcy if he should give them an assignment. They both looked through the book to find appropriate work, which Keith promptly wrote on the board. Additionally, on day four, Keith asked Darcy, "Do we have the algebra tiles?" as he is ready to hand them out to the class (focus class transcript, line 47). These three instances revolved around not setting up the materials prior to class, which Keith attributed to the lack of time. This lack of preparedness, though, did not impact the overall flow of the lesson; however, that was not the case for days three and five.

Prior to the lesson on day three, Keith indicated he felt that the students would not struggle in learning the vocabulary, stating "this is the sort of thing [the students] will pick up in seconds" (Keith, Lesson Centered Interview, day 3). He intended to focus mostly on adding and subtracting polynomials, something he was only able to do one problem with at the end of class. His lesson plan for day three was different from the other three days in that it was just the worksheet he handed out to the students. He later stated that while he knew how he wanted the lesson to progress, he had not planned in detail (fieldnotes, day 3).

As discussed in section 4.3.2.2, one specific part of the implementation Nicole and Darcy had focused on with Keith was launching the task. On day three, it was during the launching of the task with the chart of orders for bird supplies that the lesson began to unravel. Reflecting back on the lesson, Keith stated,

> I was surprised that the kids, for how smart they were, couldn't remember what a monomial was and what I binomial was...I guess I could have introduced it in a way that left more...a longer lasting understanding but the fact that they couldn't associate one term with

> monomial was surprising to me…. I had no desire to do that chart. It was in the book and I guess I didn't grasp the importance...I still don't think it was that important...but I guess I didn't grasp why it was there. Basically there [were] three different people, one of their orders was expressed by a monomial, one was a binomial and one was a trinomial. I didn't even make that connection, probably because I had no interest in that problem and I didn't want to do it but I did it because it was in the book (Keith, General Interview #2, lines 476-477; 504-507).

His lack of thinking through the launching problem and understanding the mathematical purpose to the task eventually led to a poor implementation, one in which both the teacher and students were confused.

While Keith's lesson plans for day five were more extensive than those on day three (i.e., he scripted the lesson and had specific questions to ask), it became noticeable during the class that he had not fully worked through each of the examples. As discussed earlier, this led to Keith abandoning two of the four problems, but unlike day three, it did not interfere as extensively with the focus of the lesson.

4.3.3.3 Alignment of High Expectations Section 4.3 (Keith's story) began by discussing the high expectation for success that is prevalent at Baskerville Middle School. Keith is not immune to those demands. He is aware of the expectations, feeling the demands from his mentors, his supervisor, the curriculum, and his coursework at the university. He articulated that the alignment between all of these entities is very helpful.

> It's comforting that I don't have the same worries that other interns sometimes do where Pitt's philosophy is totally different than their school's and that can cause problems sometimes where they try teach like Pitt teaches you on the one day their supervisor comes, and then they try to teach the other way when the supervisor's not there. I don't have to worry about that. It's comforting that they both believe in the same thing (Keith, General Interview #1.1, lines 397-403).

While the consistent message is valuable, he sometimes struggles with the high expectations- both in reaching them and in appreciating them. For example, Keith discussed how his experience with both his mentors and supervisor is different from other interns in the university program. He felt that compared to other interns he was held to a higher expectation of success by his mentors and supervisor. For example, he noted that "I get the impression that not all supervisors are so tough" (Keith, General Interview #2, line 285). While he also felt that this was reasonable and "good for me in the long run", he expressed that the higher expectations

> hasn't been good for my report card….The internship grade is the only thing I haven't gotten an A or an honors on since I've been here… I think...in terms of like trying to make me a better teacher it's good for me…..I'm not sure I appreciate it right now but probably at some...I don't know...in a way I do appreciate it now. In a way I...I mean I don't wish that I had someone that wasn't as involved but at the same point, at some points it would be nice. Not that I would want that, though (Keith, General Interview #2, lines 294-295; 299-301).

Darcy acknowledged that Keith is possibly held to a higher standard that others, stating that

> we are an excellent school but you've had two people who have gone through the ESP program, you're having someone...a supervisor that is like the god…you know, your daily observations are going to be a little bit more critical (Darcy, Contextual Interview, line 548).

4.4 COMPARING THE INSTRUCTIONAL PRACTICES OF PAIGE AND KEITH

There were a number of similarities between Paige and Keith. For example, both were completing a year-long internship in schools that were well respected within the communities for high academic success among students. Both were in the same teacher education program, in which the focus was on preparing pre-service teachers to develop and enact cognitively demanding, student-centered lessons. Additionally, both Paige and Keith participated in ESP, as did their mentors. Despite these similarities, an analysis of the results discussed in chapter four illuminated key differences between the instructional practices of Paige and Keith. These differences are important since they not only impact the learning that Paige and Keith take with them from their pre-service teacher experience, but ultimately affect their students' opportunities to learn mathematics (Stigler & Hiebert,1999; Hiebert, 2003). These differences are highlighted in the next two sections.

4.4.1 Instructional Practices

Both Paige and Keith relied on the curriculum as the primary source of the tasks used in their classrooms. However, the way in which they used the tasks differed. Paige appropriated all of her tasks from the curriculum, each time implementing the task in a manner that maintained the cognitive demands of the original task. Three of her five tasks focused on learning a procedure that did not require students to make connections to the underlying mathematical concepts. The end of unit project (days four and five) was high-level, requiring students to engage in activities such as making predictions and justifying. In contrast, Keith consistently changed the tasks in the curriculum. Specifically, he used a task from outside of the curriculum on day one, and modified the tasks from the curriculum on the remaining three days. He increased the cognitive demands of the tasks on three of the four tasks. Even though he adapted the task on day two, those modifications did not change the demands of the task. This was the only day he implemented a low-level task. During the implementation of the tasks, both Paige and Keith consistently maintained the level of cognitive demands of the task (high-level or low-level); however, twice they both implemented the task at a lower IQA score than the score at set-up.

Both Paige and Keith provided students with a variety of representations throughout the lessons; however, it is not just the presence of multiple representations that is vital to understanding, but rather the ways in which the representations are used as a means to develop a connected web of ideas (Lesh, Landau, & Hamilton, 1983; Lesh, Post, & Behr, 1987; Pape & Tchoshanov, 2001). As outlined in chapter one, two key components of conceptually understanding a mathematical idea are 1) being able to connect pieces of knowledge in a meaningful way (Skemp, 1976; Hiebert et al, 1997), and 2) using that knowledge to move flexibly between and among various mathematical representations (Dreyfus & Einsberg, 1996; NRC, 2001; Lesh, Post, Behr, 1987; NCTM, 2000; Pape & Tchoshanov, 2001). The conversations surrounding various representations that students in Keith's classroom engaged in were different from those that Paige's students had access to in their classroom. For example, on day one in Paige's classroom, there were 12 conversations where connections between representations were stated, but only two of these conversations were such that students were provided with the opportunity to think and reason about the relationships between the representations. In contrast, all 10 conversations where connections were made public in Keith's classroom on day one were prompted by connecting questions, thus providing the students with opportunities to advance their current thinking and understanding through further reflection, exploration, application, or analysis of mathematical relationships (Hiebert & Wearne, 1993; Driscoll, 1999; Boaler & Brodie, 2004).

As tables 20 and 21 illustrate, on average, Keith asked almost twice as many questions each day as did Paige. He was also more consistent than Paige with the number of questions he asked each day; that is, the range of total questions for Keith was 55, whereas for Paige it was 107. Interestingly, Paige asked the most questions on day two, which was a teacher-centered lesson, and the least on days four and five, each which involved a high-level task. The trend in Keith's data was opposite. He asked the least number of questions on the only day he used a low-level task, and asked a consistently higher number of questions on the days he enacted high-level tasks.

Day:	Tuning	Monitoring	Connecting	Total
1	21 (32.8%)	40 (62.5%)	3 (4.7%)	64
2	12 (9.9%)	97 (80.2%)	12 (9.9%)	121
3	0	46 (95.8%)	2 (4.2%)	48
4	0	28 (93.3%)	2 (6.7%)	30
5	0	14 (100%)	0	14
TOTALS	33 (11.9%)	225 (81.2%)	19 (6.9%)	277
Average # per day	**6.6**	**45**	**3.8**	**45.4**
Range of questions asked	**21**	**83**	**12**	**107**

Table 20: Summary of Paige Morris' questions

Day	Tuning	Monitoring	Connecting	Total
1	7 (8.4%)	49 (59%)	27 (32.5%)	83
2	0	0	0	0
3	2 (3.7%)	43 (79.2%)	9 (16.7%)	54
4	2 (2%)	60 (60.6%)	37 (37.4%)	99
5	8 (7.3%)	47 (43.1%)	54 (49.5%)	109
TOTALS	19 (5.5%)	199 (57.7%)	127 (36.8%)	345
Average # per day	**4.75**	**49.75**	**31.75**	**86.25**
Range of questions asked	**5**	**17**	**45**	**55**

Table 21: Summary of Keith Nichols' questions

A more fine grained analysis shows that it is not just the number of questions that differed, but also the types of questions asked. Keith asked each type of question each day. Altogether, 5.5% of all the questions he asked were tuning, 57.7% were monitoring, and 36.8% were connecting. Paige, however, only asked tuning questions on days one and two, and did not ask any connecting questions on day five. Additionally, the vast majority (81.2%) of all the questions Paige asked were monitoring. This was true in each class as well as overall. Only 6.9% of the total questions asked were connecting. The difference in the types of questions asked is striking, particularly regarding connecting questions. Questions of this type are focused on providing students with opportunities to grapple with, reflect on, or further analyze the key mathematical ideas of the lesson, or to make conceptual connections between various representations. Overall, Keith asked six times as many connecting questions as did Paige. Keith's least number of connecting questions occurred on the day he used a procedural task.

However, even on this day 16.7% of his questions were connecting, as compared to the highest number Paige asked- 9.9%- which also occurred during a procedural task. Paige asked either few (6.7% on day four) or no (day five) connecting questions when she used a high-level task. This is intriguing, given that the nature of high-level tasks is such that connecting questions are a natural fit. High-level tasks focus on exploring and analyzing concepts and relationships and as a means to develop meaning for the underlying mathematics of the task (Stein and Lane, 1996; Stein et al, 2000). Connecting questions are designed to elicit that thinking from the students (Hiebert & Wearne, 1993; Driscoll, 1999; Newton, 2002; Boaler & Brodie, 2004).

4.4.2 The contextual settings

There were many similarities between the contexts in which Paige and Keith taught. The schools were similar in composition and scored comparably on state assessments. The mentor teachers each participated in ESP, and as such, had been exposed to what the University valued regarding instructional practices. According to Boston's (2006) study, both Michelle and Madeline were using high-level tasks in their own teaching, and Darcy was recognized within the University as being a teacher leader who also frequently used high-level tasks. Each of the focus classes used traditional textbooks. Additionally, each of the University supervisors visited the classroom regularly to observe and provide feedback. Despite these similarities, however, there existed critical differences, particular regarding the use of the curriculum and the interactions of each pre-service teacher with the mentors and supervisors.

Paige and Keith both used a traditional textbook for the focus class. Their views of and reliance on the textbook, though, was quite different. As shown in section 4.2.2.2, Paige consistently appropriated the tasks from the curriculum. From her perspective the textbook was a valuable resource that supported her desired teaching practices. She described the suggestions in the teacher's addition, stating that

> on the side it has different things but the things I use the most are probably just the additional example questions...sometimes it will have…questions laid out that I'll be like, "Oh! That's a good question to ask."...but there's the typical…if you have English as a second language try this. Or if you have a student with this try this. Or, if you want to do this individually instead of group or vice versa you could do this. So...they're good suggestions, I mean, in general. Paige, General Interview #1, lines 254-259)

Paige viewed the Integrated One text as "student-centered", stating that,

> almost daily they have to do something in their groups...it might just be a simple calculator activity or finishing a couple of questions together but there's a lot of different...just activities thrown in (Paige, General Interview #1, line 159).

However, an analysis of the tasks in the curriculum showed that 60% of the tasks associated with the days of observation focused on practicing procedures and did not require students to think and reason meaningfully about mathematical concepts. These tasks appeared to by typical of the tasks throughout the textbook.

Keith did not value the structure of the traditional text, stating that "it tells you how to do something and then gives you a bunch of examples" (Keith, General Interview #1, line 154). Keith's practice was highly influenced by his use of the reform-oriented curricula, CMP, which was used in the other math classes he taught. As previously stated in section 4.3.1.2, Keith described ways that he and Darcy "combat" the traditional approach of the Prentice Hall text, trying to make it more like CMP. When asked to describe the mathematics in the textbooks, he stated that "Prentice Hall is easier but I think that [the students] get a better understanding from Connected Math" (Keith, General Interview, line 157). Additionally, as described in section

4.3.2.2 Keith relies greatly on the teaching suggestions from CMP; however, he stated that he does not use any of the teaching suggestions in the traditional text because he does not find them helpful to him in designing the lessons.

In addition to the textbook, the mentoring practices that Paige and Keith experienced were also different. Paige and Madeline both stated, and field notes confirmed, that they regularly co-taught classes. This was particularly true of the second period class; however, Madeline also regularly interjected comments and questions during the other classes Paige taught. Interestingly, though, Paige and Madeline did not discuss *why* Madeline interjected a comment or question in a particular way at a particular time. Additionally, as discussed in section 4.2.3.4, the feedback that Paige received on her teaching was general and broad. Keith's experiences with his mentors were different. He did not co-teach with either of his mentors. Instead, as outlined in section 4.3.3.1, Michelle and Darcy made detailed notes during his lessons and provided him with specific feedback after class. Keith's mentors and university supervisor all mentioned that he was slow to implement the feedback; however, no comparison to Paige can be made on this aspect since she did not receive the same type of feedback and guidance.

5.0 CHAPTER FIVE: DISCUSSION

5.1 INTRODUCTION

Chapter one described the need for the instructional practices in mathematics classrooms to shift from procedure driven teacher-centered instruction to conceptually oriented student-centered instruction. However, research indicates that this process is not easy for teachers to accomplish (Cohen, 1990; Manouchehri & Goodman, 2000; Orrill & Anthony, 2003; Wilson & Lloyd, 2000). Teachers need experience. Teacher education programs have the potential to provide pre-service teachers with opportunities both in the university setting (e.g. Behm & Lloyd, 2003; Lloyd & Frykholm, 2000; Smith et al, 2001; Smith et al 2003; Spielman & Lloyd, 2004) and in the field experience classroom (e.g. Eisenhart et al, 1994; Ebby, 2000; Van Zoest & Bohl, 2002) to develop instructional practices that support students' development of mathematical understanding that is conceptual rather than purely procedural in nature.

Drawing on Carpenter and Lehrer's (1999) framework, this study investigated the instructional practices of two pre-service teachers. Specifically, this study examined the cognitive demands of the tasks used in focus lessons at four particular points (curriculum, lesson plan, set-up, and enactment), the type of academic questions asked (tuning, monitoring, and connection), and the representations of functions (table, graph, equation, language, and context) available during the lesson. Previous research (e.g., Clarke, 1997; Henningsen & Stein, 1997; Hienert & Wearne, 1993; Lloyd, 1999; Remillard, 1999; Sanches & Llinares, 2003; Van Zoest &

Bohl, 2002) indicated that various factors impact the implementation of instructional practices that involve conceptually oriented tasks. Additionally, this study investigated how aspects of the context within which each pre-service teacher worked influenced their instructional practices, particularly focusing on the mentor teacher and the curriculum.

Findings from the study show that the instructional practices of Paige and Keith were quite different. Paige appropriated all the tasks from the textbook and stated that she felt the textbook aligned with her teaching methods. Keith, however, stated that he did not value the traditional text in the focus class, but instead preferred the methods of the ROC he used in his other classes. As a result, he supplemented the textbook with a task from an outside source on the first day and adapted the tasks in the textbook to be more "CMP-like" on the remaining three days. Even the lesson plan format that Paige and Keith utilized was quite different. Paige used a chart that simply contained the objective, page numbers from the textbook, and problem numbers for homework. In contrast, Keith's lesson plans typically were 2-4 pages of text that included details such as specific questions to ask the students.

There were also differences on each of the critical dimensions of instructional practice. While both Paige and Keith consistently maintained the level of cognitive demand of each lesson, only 40% of Paige's tasks (2 out of 5) were high-level, compared to 75% (3 out of 4) of Keith's being high level. Both Paige and Keith did provide their respective students with multiple representations; however, the ways in which the representations were used differed. Paige focused on procedural aspects of making connections between representations. Keith used the representations as a way for the students to build meaning of the mathematical concepts. Paige was also more likely to state connections, whereas Keith often asked questions that allowed the students to make the connections. This is most evident in the questions that each pre-service teacher asked. On average, Paige asked only 4 connecting questions per day, compared to Keith's average of approximately 32.

When taken together, the data indicate that students in Keith's class were exposed to more tasks that were cognitively demanding (i.e, 75% of the tasks were high-level as compared to 40% of Paige's tasks), and to more opportunities via the questions asked to make connections between representations and to the mathematical concepts. This is important since previous research (as reviewed in chapters one and two) indicates that the critical dimensions of instructional practice impact students' learning. Specifically, studies by Hiebert and Wearne (1993), Stein and Lane (1996), and Stigler and Hiebert (1999) illustrate that the cognitive demands of the tasks used in a classroom influence the opportunities students have to think and reason about mathematics. The work of those such as Lesh, Landau, and Hamilton (1983), Lesh, Post, and Behr (1987), and Pape and Tchoshanov (2001) point to the importance of students making connections between representations as a way to develop a conceptual understanding of mathematics. Additionally, studies by Chapin et al (2003), Forman et al (1998), Hiebert and Wearne (1993), Lampert and Rittenhouse (1996), Martino and Maher (1999) and O'Connor (2001) demonstrate how the types of questions asked can impact the students' learning of the mathematics. Keith's students, then, were provided with more opportunities to think and reason about mathematics and develop a conceptual understanding.

One possible explanation for these differences is that Paige and Keith themselves had different experiences regarding their learning about instructional practices. The next section further considers the opportunities that Paige and Keith had during their field experience to learn about student-centered instructional practices.

5.2 OPPORTUNITIES TO LEARN ABOUT STUDENT-CENTERED INSTRUCTIONAL PRACTICES DURING THE FIELD EXPERIENCE

One well established idea in education research is that students learn what they have the opportunity to learn. While this research has focused on K-12 students, it stands to reason that the same is true if the students are pre-service teachers learning the teaching profession. That is, pre-service teachers can only gain knowledge of ideas and become skilled at methods to which they are exposed to and have opportunities to explore. Varied experiences are likely to result in varied learning outcomes.

As previously established, Paige and Keith did have a number of similar experiences, yet their instructional practices were quite different. One way to account for these differences is by more closely comparing support structures of each pre-service teacher. An analysis of the contexts makes salient the differences in the support to enact student-centered instruction between each pre-service teacher. Two specific areas that were targeted in this study were the curriculum and the mentor. A review of the data indicated that the curriculum used in each part of the field experience (i.e., not just the focus class) did impact the instructional practices of both Paige and Keith. Additionally, the mentoring that Paige and Keith received from their mentor teachers and university supervisors also appeared to affect aspects of their practice. Each of these are explored more in the following sections.

5.2.1 The curriculum

Chapter one discussed that the textbook is a primary support that teachers rely on for planning and teaching mathematics (Brown & Edelson, 2004; Ball & Cohen, 1996; Remillard, 2004; Van Zoest & Bohl, 2002). Traditional textbooks and ROC differ significantly on the types of mathematical thinking and reasoning that is valued as evidenced by the tasks that are provided to engage students with the mathematics. In addition, the curricula also diverge on the role of the teacher and the students (Lloyd, 1999; Lloyd & Frykholm, 2000, NCTM, 1989; NCTM, 2000; Senk & Thompson, 2003b). As a result, different curricula provide differing levels of support to teachers who are trying to implement student-centered instructional practices.

As discussed in section 4.2.2, the curricula that Paige and Keith were each exposed to seemed to impact their instructional practices. Even though both pre-service teachers used a traditional textbook in the focus class, Keith had access to and experience with the reform-oriented curriculum CMP. Paige viewed her curriculum as a great resource that supported her desired instructional practice. She cited the suggestions from the teacher's edition as support; however, as previously discussed, the suggestions in the Integrated 1 textbook were primarily surface level features rather than substantial support for enacting student-centered instructional practices. Through CMP, Keith did have access to a curriculum that provided substantial support. Keith was able to utilize his exposure to and experience with CMP in his other classes to modify his instructional practices with the traditional textbook in the focus class.

5.2.2 Mentoring

As described in chapter one, the mentor can have a profound influence on the instructional practices of a pre-service teacher (Ebby, 2000; Eisenhart et al, 1994; Frykholm, 1996; Van Zoest and Bohl, 2002). Mentors can be a support and socializing agent to the teaching profession for the pre-service teacher (Little, 1990). The act of mentoring can serve as an effective tool for helping pre-service teachers learn to teach because there are aspects of teaching that can only truly be explored while in the classroom setting rather than a university course (Feiman-Nemser, 2001; Wang, 2001).

In pre-service teacher education, the term "mentor" is often used to describe the teacher of the classroom in which the pre-service teacher is completing some component of the field experience; however, the term mentor can be extended to others with expertise in the field who are involved on a regular basis with the pre-service teacher regarding their teaching practices, such as the university supervisor (Little, 1990). Using Little's (1990) definition, both the mentor teacher and the university supervisor played mentoring roles for Paige and Keith. However, the depth of mentoring that each received was quite different, thus providing different opportunities to progress towards the goal of student-centered instructional practices.

Feiman-Nemser (2001) describes two types of mentoring practices: *emotional support* and *educative mentoring*. Drawing on the work of Little (1990), Feiman-Nemser defines emotional support as, "support that makes novices feel comfortable" (p.18). Emotional support mentors typically view their role as primarily providing a classroom in which the pre-service teachers[14] can try out new ideas, succeeding or making mistakes in a safe context. The support given may take the form of offering suggestions and feedback, but the nature of the support "may not

[14] While each study discussed did involve pre-service teachers, the studies more broadly focused on beginning teachers; however, for consistency within the text of this current study, the term "pre-service teacher" will be used. The author recognizes that this is limiting, but wishes to use a consistent vocabulary.

qualify as an educational intervention" because it may be very situation specific or practical advice that does not provide an opportunity for the pre-service teacher to learn about a key aspect of teaching (Feiman-Nemser, 1998). In contrast, educative mentoring is guided by

> an explicit vision of good teaching and an understanding of teacher learning. Mentors who share this orientation attend to beginning teacher' present concerns, questions, and purposes without loosing sight of long-term goals for teacher development. They interact with novices in ways that foster an inquiring stance. They cultivate skills and habits that enable novices to learn in and from their practice. They use their knowledge and expertise to assess the direction novices are heading and to create opportunities and conditions that support meaningful teacher learning in the service of student learning (p. 18).

Various research studies (e.g., Feiman-Nemser, 1998, 2001; Edwards, 1998; Wang 2001) indicate that educative mentoring is a powerful tool in helping beginning teachers develop instructional practices that are conceptually oriented and student-centered. Feiman-Nemser (2001) discussed how the educative mentor relates to the beginning teacher in a way that is similar to the desired way the beginning teacher should interact with the students in the classroom. For example, she identified eight strategies one exceptional educative mentor used with a beginning teacher. Specifically, she found that the educative mentor 1) found appropriate openings to discuss key ideas, 2) helped the beginning teacher pinpoint the source of any problems, 3) probed the thinking and reasoning of the beginning teacher, 4) commented on points of growth, 5) remained focused on student learning, 6) connected to relevant theories of teaching and learning, 7) provided a model of desired teaching for the beginning teacher to observe, and 8) demonstrated "wondering about teaching" via reflection and questioning. In sum, educative mentoring is purposeful and occurs in all phases of teaching- planning, enacting, and reflecting (Feiman-Nemser, 1998, 2001). .

As described in section 4.2.3.4, the feedback that Paige typically received from both Madeline and Derrick was broad, often involving complementary comments or general pieces of advice. This is indicative of the *emotional support* mentoring (Fieman-Nemser, 2001). While supporting the pre-service teacher via general feedback and advice is sometimes appropriate, the problem arises when the majority of mentoring is in this format, as was the case with Paige. Beginning teachers often do not know how to ask for specific guidance and feedback, or do not even recognize that it is needed and would be beneficial to their teaching practices (Little, 1990). In contrast, as illustrated in section 4.3.3.1, Keith was consistently exposed to *educative mentoring* from both of his mentor teachers and university supervisor. He was expected to work towards a high standard of success, and was provided with very specific feedback about his instructional practices along the way. The mentoring that Paige and Keith received is a critical component of their experiences, and the differences ultimately may have impacted their instructional practices. A recent study by Fieman-Nemser (2001) indicated that beginning teachers within the first few years of teaching who were exposed to educative mentoring were more likely to develop effective instructional practices that were student-centered and conceptually oriented and go beyond the surface level features of reform instruction (e.g having students work in groups). One possible explanation for the differences in the mentoring practices may be the way each mentor and supervisor viewed their role and purpose with the pre-service teacher as well as their expectations of the pre-service teacher.

Both Madeline and Derrick stated that their role with Paige was primarily to provide support for her while she figures out the “nuts and bolts of teaching” (Madeline, Contextual Interview, line 409). Madeline stated that in addition to providing a model of good teaching, she wanted to "also just to support her....you know, if there's an issue and she needs my advice, I'm there to help her with it" (Contextual interview, line 410-411). Derrick described his relationship with Paige as one that was very collegial.

> Well, actually I believe from day one, it really didn't have that feeling at all that we were different. It was more like we were just co-workers on this deal and ....I never got the feeling that she was nervous that I was coming in or she was afraid of me or anything of that type at all. She was just very friendly and that was the way she was with [Madeline], too. It's just like everybody was equal and she was equal to us and we were equal to her and we're all in this together (Derrick, Contextual Interview, lines 47-50).

Additionally, Derrick's description of his approach to supervising pre-service teachers aligns with that of an emotional support mentor.

> I don't approach my supervising with…expectations, I think. I think I just go and see what the situation is, then see what I can do to help or what advice I can offer or uh...like some...some schools, some districts, some mentor teachers...they don't know what to do with an intern or student teacher. So I tell them about my past experiences or what I...what I think the university would want. With [Paige] and [Madeline],...they were both very confident. [Madeline's] been through the [same university] program so she knew...what was kind of expected. And...really with [Paige] there wasn't much to do. She was on top of things right from the very beginning (Contextual Interview, lines 69-75)

Paige also discussed her perspective on what Madeline and Derrick expected from her as an intern.

> I think that [Madeline] kind of expects me to do the same things she does…. do everything for the classes that I'm teaching at the time,...planning and…teaching, figuring out…pacing and dealing with whatever issues pop up in that class. So, on that level I pretty much… do whatever she's doing…I go to all the meetings that we need or parent

> meetings or team meetings or IEP meetings (General Interview #1, lines 310-315).
>
> [Derrick] expects me to do a good job and, you know, to keep things running smoothly….Make sure that I'm listening to the kids. Make sure that… that I'm clear....If the kids are engaged or not, or if they could care less what's going on….[Derrick] is such a nice guy so it's hard to… think of what he's so critical about. He always tries to be so nice about it. (General Interview #2, lines 138; 143-147)

As illustrated in section 4.3.3.3, Keith recognized that he was being held to a high standard of success from his mentors and university supervisor. This difference is further illuminated by his mentors' and supervisor's expectations and views of their roles with Keith. Each of them independently stated that the expected Keith to plan and enact lessons that provides students with opportunities to engage in thinking and reasoning about mathematics. That is, he should identify a meaningful goal and create a lesson that facilitates students working towards that goal. Each emphasized the value of a well-written lesson plan, and Darcy repeatedly commented on the importance of referring to the written plan during the enactment. Additionally, each discussed the expectation that Keith should reflect on the enactment of the lesson, and through that reflection identify one or two specific areas to work on immediately.

Darcy, Michele, and Nicole's description of their roles closely aligns with that of an educative mentor. For example, Nicole stated that her approach to working with pre-service teacher was to

> try to take notes on what's actually happening during the lesson and then try to identify with the teacher some area of instruction which they need...which they feel they need to continue to work on. And then trying to use...the evidence collected during the lesson as a way to frame the discussion about whatever that particular thing is (Contextual Interview, lines 76-77).

This focused and purposeful observation and conversation was typical of the interactions Keith had with Darcy and Michele during the course of the data collection.

Throughout the data collection, Paige only had opportunities to experience two of the eight characteristics identified by Feiman-Nemser (2001): commenting on points of growth and observing desired teaching practices. However, these opportunities were not fully capitalized on as an authentic way of promoting growth. For example, as previously established, the feedback Paige received was often general in nature. Additionally, even though Paige did have opportunities to watch Madeline teach, Paige stated that from the first day of her internship, she "never just sat and observed" (General Interview #1, line 104).

Keith's experience being mentored was quite different than Paige's. Through the interviews and observations, there is evidence that Keith regularly experienced all eight of the characteristics associated with educative mentoring as described by Feiman-Nemser (2001). His mentors often focused on a particular part of his lesson and used those as a way to discuss student understanding as well as actions Keith did or did not take to support students' learning of the intended mathematical goal.

Another difference of interest between the mentoring of the university supervisors was the extent to which each viewed the role of the university in the education of the pre-service teachers. Feiman-Nemser's (2001) sixth criteria of an educative mentor is that the mentor helps the pre-service teacher see connections to relevant theories of teaching and learning; that is, the instructional practices of the pre-service teacher should be informed by and viewed through the lens of the current understanding of effective teaching strategies. Nicole's interactions with Keith were, in fact, grounded in relevant theories that Keith was learning about at the university. This may be due, in large part, to the fact that Nicole was also an instructor for two of Keith's methods classes at the university. As discussed in section 4.3.3.3, Keith recognized and appreciated the consistency between his field placement and university coursework. In contrast, Derrick indicated that he did not value the work of the university, as he did not view the workload and assignments as being beneficial to the pre-service teachers. He expressed his concern, stating,

> I get the feeling...at least the last two, maybe three years, that [the pre-service teachers are] being overworked down at Pitt. [Those] who are teaching those courses are...[the pre-service teachers are] doing a full-time job at their school and then they're doing a full-time job at Pitt. It's very, very frustrating to them. At different times, different interns, they just get overwhelmed and I've talked to them and their mentors and people have talked to them and kind of get them through it and then after that things turn around. It seems like the workload down at Pitt is too much. That's my observation of the whole thing….[The university work] keeps them away...yes...it keeps them away from the preparation for their local...for their schools (Contextual Interview, lines 247-249; 260).

In summary, the mentoring practices that Paige and Keith were each exposed to were quite different. Paige experienced emotional support that focused on helping her deal with problems as they arise. Keith's mentors (including his university supervisor) were more purposeful in their observations and feedback. They consistently used specific instances form the lesson as a means to identify key areas for Keith to focus on improving.

5.3 IMPLICATIONS AND RECOMMENDATIONS FOR THE FIELD

This study examined the instructional practices of two secondary mathematics pre-service teachers. The results indicate that the curriculum used, the alignment of support, and the mentoring practices each pre-service teacher was exposed to impacted their instructional practices, particularly with respect to the cognitive demands of the tasks used in the classroom, the use of representations as a means to build understanding of a concept, and the number of and types of questions asked during the enactment of the lesson. These results have significance for the field of pre-service teacher education.

First, as outlined in section 5.3.1, both Keith and Paige relied on their curriculum as a resource for planning lessons. Each focus class used a traditional textbook. Keith, however, was more critical of the traditional book than Paige. Paige described her curricula as being "student-centered", but she focused on surface level features such as suggestions for working in groups. While working in groups can be a powerful experience for students, being in groups does not guarantee that the students will effectively engage in a mathematically productive conversation. The group work needs to be purposefully structured so that the students are thinking and reasoning about mathematics. Paige's curriculum did not provide her with the support necessary to construct this type of setting. Similarly, the teacher's edition from Keith's focus class also did not provide this support; however, CMP did. Keith used the ideas in the reform-oriented curricula he used in other classes as a guide to modify the more traditional text used in the algebra focus class. Given that pre-service teachers are likely to rely heavily on their textbooks, pre-service teacher education programs should consider providing opportunities for their students to explore a variety of curricular materials, critically analyzing the tasks, tools, and normative practices provided. Additionally, pre-service teachers should analyze the benefits and drawbacks of different curricula.

Second, as illustrated in Keith's story, the alignment of high expectations from various aspects of the context in which the pre-service teacher is immersed (i.e., curriculum, mentor, supervisor, university courses) was effective in supporting the development of student-centered instructional practices. Paige's context was not fully aligned, given that the curriculum was a traditional text and her supervisor did not value the practices of the university courses. This result implies that pre-service teacher education programs should carefully examine the extent to which all aspects of the pre-service teacher's context aligns to support and promote the desired instructional practices.

Finally, this study highlights the importance of mentoring on pre-service teachers instructional practices. Specifically, Keith experienced educative mentoring, and he was more likely than Paige to plan lessons that involved high-level tasks and to maintain the cognitive demands of the tasks during the set-up and enactment of the lesson. Thus, the mentoring that pre-service teachers experience is a critical component in developing student-centered instructional practices. Teacher education programs, then, should carefully consider the identification and use of mentors, including the university supervisors. According to a study by Wang (2001), even if the mentor teacher's instructional practices are student-centered and represent the practices desired from the pre-service teacher, that alone does not imply that the mentor will be effective in helping the pre-service teacher develop those practices. This is illustrated with the case of Madeline and Paige. Boston's (2006) study indicated that the majority of tasks that Madeline used in her classroom were high-level, and that she maintained the cognitive demands of the tasks during the enactment of the lesson; yet only 20% of the tasks that Paige enacted were high-level. Paige's story exemplifies the fact that educative mentoring is not guaranteed simply based on the practices of the mentors. Therefore, teacher education programs also should establish ways of working with the mentors on the act of mentoring. Comments from both Madeline and Michele support the ideas that teacher education programs need to provide support and feedback to the mentors. Both indicated that they were unsure of how to progress in mentoring, particularly in the beginning stages of the internship. Each also expressed a desire for feedback on their mentoring practices.

5.4 FUTURE RESEARCH

While much was learned from this study, there were limitations in the design that should be considered in future research. This study focused on two participants, each for five consecutive days. Future research may focus on a longer time frame as a way to capture more detail and note changes that may (or may not) occur over time. Future work may also include a larger number of participants in a variety of setting. Additionally, this study focused primarily on the curriculum and the mentor teachers. Future studies might more closely examine other support structures available to the pre-service teachers. For example, future research should examine more specifically the role of the university supervisors, focusing on the feedback provided and the impact that feedback has on the instructional practices of the pre-service teacher. Additionally, future research should follow the participants in university methods courses as a way to investigate how the tools and frameworks of the program are introduced and utilized in the university course. This would provide more insight into the alignment between the expectations and support of university regarding the enactment of student centered instructional practices with the expectations and support of the mentor teachers and university supervisors.

The research could also be expanded by following the pre-service teachers into their first year of teaching to determine the nature of their instructional practices when they are no longer "under the wing" of the mentor teacher and university supervisor. The support available to Paige and Keith during the first year of teaching may be similar to or different from the access each had to educative mentoring and a reform-oriented curriculum as pre-service teachers. A study that examines their instructional practices and how the new contextual settings impact those practices would provide insight into what residue, if any, remained from their experiences as a pre-service teacher as well as how instructional practices may change or stay the same when different supports are in place.

Appendix A

TOOLS AND FRAMEWORKS INTRODUCED IN THE UNIVERSITY METHODS COURSES

Thinking Through a Lesson Protocol
TTLP

Part 1: Selecting and Setting up a Mathematical Task

- What are your mathematical goals for the lesson (i.e., what is it that you want students to know and understand about mathematics as a result of this lesson)?

- In what ways does the task build on students' previous knowledge? What definitions, concepts, or ideas do students need to know in order to begin to work on the task? What questions will you ask to help students access their prior knowledge?

- What are all the ways the task can be solved?
  - Which of these methods do you think your students will use?
  - What misconceptions might students have?
  - What errors might students make?

- What are your expectations for students as they work on and complete this task?
  - What resources or tools will students have to use in their work?
  - How will the students work -- independently, in small groups, or in pairs -- to explore this task? How long will they work individually or in small groups/pairs? Will students be partnered in a specific way? If so in what way?
  - How will students record and report their work?

- How will you introduce students to the activity so as not to reduce the demands of the task? What will you hear that lets you know students understand the task?

Part 2: Supporting Students' Exploration of the Task

- As students are working independently or in small groups:
  - What questions will you ask to focus their thinking?
  - What will you see or hear that lets you know how students are thinking about the mathematical ideas?
  - What questions will you ask to assess students' understanding of key mathematical ideas, problem solving strategies, or the representations?
  - What questions will you ask to advance students' understanding of the mathematical ideas?
  - What questions will you ask to encourage students to share their thinking with others or to assess their understanding of their peer's ideas?

- How will you ensure that students remain engaged in the task?
  - What will you do if a student does not know how to begin to solve the task?
  - What will you do if a student finishes the task almost immediately and becomes bored or disruptive?
  - What will you do if students focus on non-mathematical aspects of the activity (e.g., spend most of their time making a beautiful poster of their work)?

Part 3: Sharing and Discussing the Task

- How will you orchestrate the class discussion so that you accomplish your mathematical goals? Specifically:
  - Which solution paths do you want to have shared during the class discussion? In what order will the solutions be presented? Why?
  - In what ways will the order in which solutions are presented help develop students' understanding of the mathematical ideas that are the focus of your lesson?
  - What specific questions will you ask so that students will:
    - make sense of the mathematical ideas that you want them to learn?
    - expand on, debate, and question the solutions being shared?
    - make connections between the different strategies that are presented?
    - look for patterns?
    - begin to form generalizations?

- What will you see or hear that lets you know that students in the class understand the mathematical ideas that you intended for them to learn?

- What will you do tomorrow that will build on this lesson?

The Thinking Through a Lesson Protocol was developed through the collaborative efforts (lead by Margaret Smith, Victoria Bill and Elizabeth Hughes) of the mathematics team at the Institute for Learning and faculty and students in the School of Education at the University of Pittsburgh.

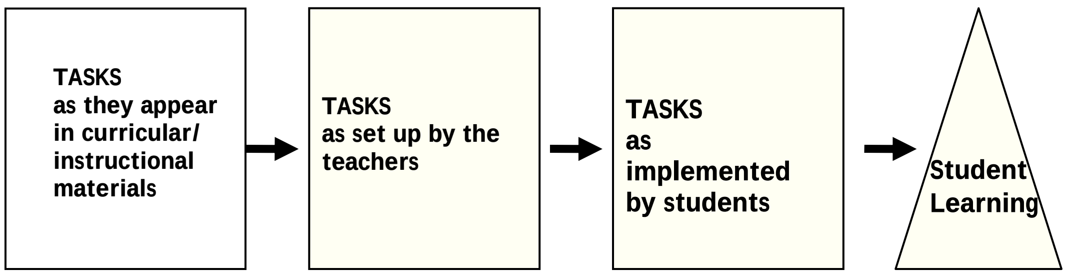
Smith, M.S. & Bill, V. (2004, January). Thinking Through A Lesson: Collaborative Lesson Planning as a Means for Improving the Quality of Teaching. Presentation at the annual meeting of the Association of Mathematics Teacher Educators, San Diego, CA.

Hughes, E.K., & Smith, M.S. (2004, April). Thinking Through a Lesson: Lesson Planning as Evidence of and a Vehicle for Teacher Learning. Poster presented as part of a symposium, "Developing a Knowledge Base for Teaching: Learning Content and Pedagogy in a Course on Patterns and Functions " at the annual meeting of the American Educational Research Association, San Diego, CA

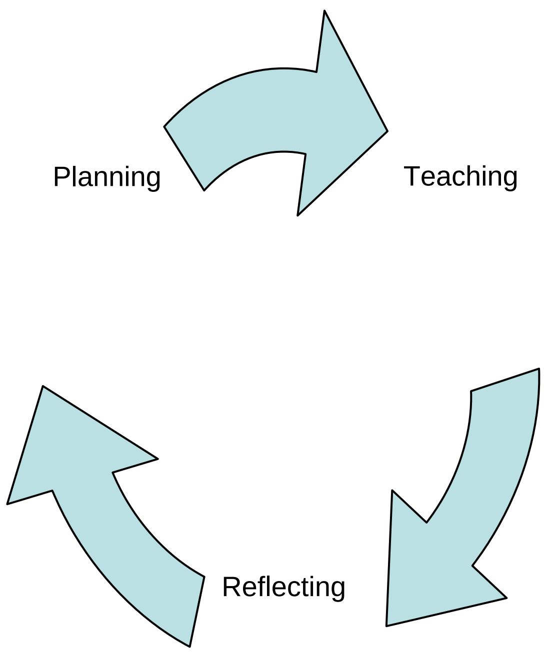
Math Task Analysis Guide

Lower-Level Demands	**Higher-Level Demands**
Memorization Tasks • Involves producing previously learned facts, rules, formulae, or definitions OR committing facts, rules, formulae, or definitions to memory. • Cannot be solved using procedures because a procedure does not exist or because the time frame in which the task is being completed is too short to use a procedure. • Are not ambiguous – such tasks involve exact reproduction of previously seen material and what is to be reproduced is clearly and directly stated. • Have no connection to the concepts or meaning that underlie the facts, rules, formulae, or definitions being learned or reproduced.	Procedures With Connections Tasks • Focus students' attention on the use of procedures for the purpose of developing deeper levels of understanding of mathematical concepts and ideas. • Suggest pathways to follow (explicitly or implicitly) that are broad general procedures that have close connections to underlying conceptual ideas as opposed to narrow algorithms that are opaque with respect to underlying concepts. • Usually are represented in multiple ways (e.g., visual diagrams, manipulatives, symbols, problem situations). Making connections among multiple representations helps to develop meaning. • Require some degree of cognitive effort. Although general procedures may be followed, they cannot be followed mindlessly. Students need to engage with the conceptual ideas that underlie the procedures in order to successfully complete the task and develop understanding.
Procedures Without Connections Tasks • Are algorithmic. Use of the procedure is either specifically called for or its use is evident based on prior instruction, experience, or placement of the task. • Require limited cognitive demand for successful completion. There is little ambiguity about what needs to be done and how to do it. • Have no connection to the concepts or meaning that underlie the procedure being used. • Are focused on producing correct answers rather than developing mathematical understanding. • Require no explanations, or explanations that focus solely on describing the procedure that was used.	Doing Mathematics Tasks • Requires complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly suggested by the task, task instructions, or a worked-out example). • Requires students to explore and to understand the nature of mathematical concepts, processes, or relationships. • Demands self-monitoring or self-regulation of one's own cognitive processes. • Requires students to access relevant knowledge and experiences and make appropriate use of them in working through the task. • Requires students to analyze the task and actively examine task constraints that may limit possible solution strategies and solutions. • Requires considerable cognitive effort and may involve some level of anxiety for the student due to the unpredictable nature of the solution process required.

Math Task Framework



Cycle of Teaching

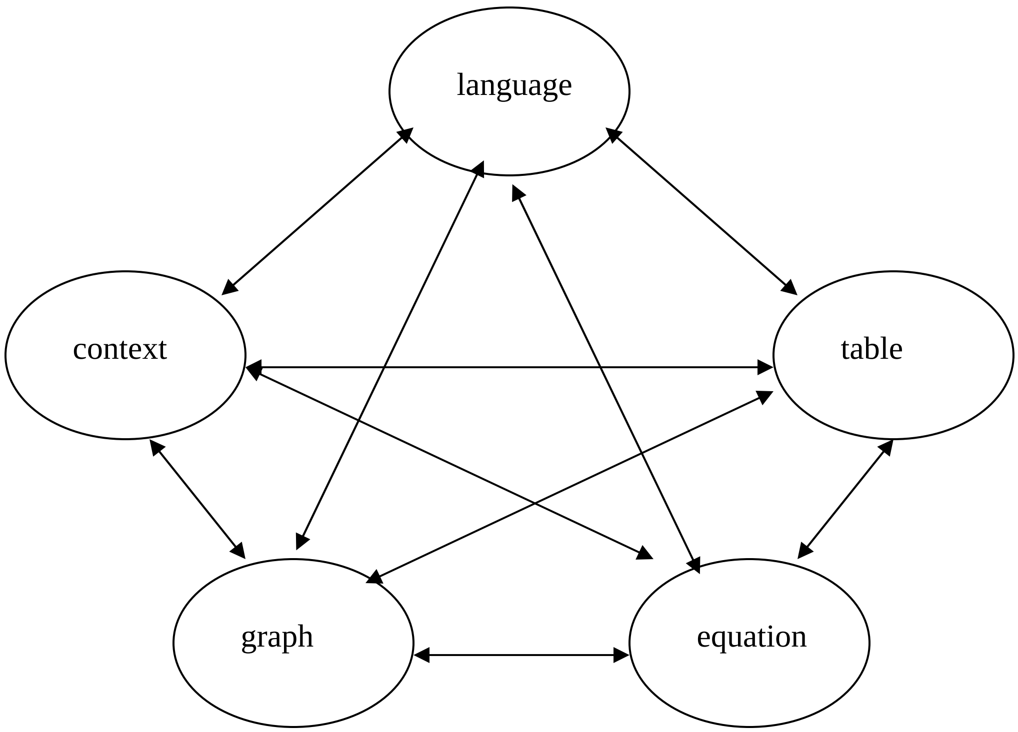


Categories of Questions

Question Type	Description	Examples
1. Gathering information, leading students through a method	Requires immediate answer Rehearses known facts/procedures Enables students to state facts/procedures	What is the value of x in this equation? How would you plot that point?
2. Inserting terminology	Once ideas are under discussion, enables correct mathematical language to be used to talk about them	What is this called? How would we write this correctly?
3. Exploring mathematical meanings and/or relationships	Points to underlying mathematical relationships and meanings. Makes links between mathematical ideas and representations	Where is this x on the diagram? What does probability mean?
4. Probing, getting students to explain their thinking	Asks students to articulate, elaborate or clarify ideas	How did you get 10? Can you explain your idea?
5. Generating Discussion	Solicits contributions from other members of class.	Is there another opinion about this? What did you say, Justin?
6. Linking and applying	Points to relationships among mathematical ideas and mathematics and other areas of study/life	In what other situations could you apply this? Where else have we used this?
7. Extending thinking	Extends the situation under discussion to other situations where similar ideas may be used	Would this work with other numbers?
8. Orienting and focusing	Helps students to focus on key elements or aspects of the situation in order to enable problem-solving	What is the problem asking you? What is important about this?
9. Establishing context	Talks about issues outside of math in order to enable links to be made with mathematics	What is the lottery? How old do you have to be to play the lottery?

Boaler & Broodie, 2004

Representations of a Function



Van de Walle (2004)

Appendix B

UNIVERSITY GUIDELINES FOR PHASE-IN OF INTERNS

University

Intern Teacher Phase-In Process

WEEK NUMBER	MAT
WEEK 1	• Induction and Observations
WEEK 2	• Induction and Observations • Routine clerical, classroom, non-instructional tasks • Individualized student instruction-tutoring, remedial or enrichment, writing/reading conferences • Small group instruction • Episodic teaching/mini-lessons
WEEK 3	• Observations • Routine clerical, classroom, non-instructional tasks • Individualized student instruction-tutoring, remedial or enrichment, writing/reading conferences • Small group instruction • Episodic teaching/mini-lessons
WEEK 4	• Routine clerical, classroom, non-instructional tasks • Individualized student instruction-tutoring, remedial or enrichment, writing/reading conferences • Small group instruction • Episodic teaching/mini-lessons
WEEK 5	• Routine clerical, classroom, non-instructional tasks • Individualized student instruction-tutoring, remedial or enrichment, writing/reading conferences • Small group instruction • Episodic teaching/mini-lessons • **One class preparation (Secondary Level: multiple sections, if possible)**
WEEK 6	• Routine clerical, classroom, and non-instructional tasks • Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • One class preparation (Secondary Level: multiple sections, if possible)
WEEK 7	• Routine clerical, classroom, and non-instructional tasks • Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • One class preparation (Secondary Level: multiple sections, if possible)
WEEK 8	• Routine clerical, classroom, and non-instructional tasks • Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • One class preparation (Secondary Level: multiple sections, if possible)
WEEK 9	• Routine clerical, classroom, and non-instructional tasks

	• Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • One class preparation (Secondary Level: multiple sections, if possible)
WEEK 10	• Routine clerical, classroom, and non-instructional tasks • Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • One class preparation (Secondary Level: multiple sections, if possible)
WEEK 11	• Routine clerical, classroom, and non-instructional tasks • Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • One class preparation (Secondary Level: multiple sections, if possible)
WEEK 12	• Routine clerical, classroom, and non-instructional tasks • Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • **TWO class preparations (Secondary Level: multiple sections, if possible)**
WEEK 13	• Routine clerical, classroom, and non-instructional tasks • Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • TWO class preparations (Secondary Level: multiple sections, if possible)
WEEK 14	• Routine clerical, classroom, and non-instructional tasks • Individualized student instruction • Small group instruction • Episodic Teaching/mini lessons • TWO class preparations (Secondary Level: multiple sections, if possible)
WEEK 15	*NOTE: This schedule should continue until* ***WEEK 18.*** *At that time the intern will assume ½ of the mentor's teaching schedule (****no more than 3 preparations/day at secondary level)****. This will continue for the rest of the placement.*

Phasing in of interns and student teachers is <u>always</u> a joint decision and deviations from these guidelines to accommodate individual student's progress should be made only with the consent of the intern/student teacher, the mentor/cooperating teacher, and the university supervisor.

For additional information, you should refer to the <u>Intern or Student Teacher Handbook</u>.

Appendix C

UNIVERISTY GUIDELINES FOR ROLES OF THE MENTOR, SUPERVISOR, AND INTERN

SUMMARY OF THE ROLES OF THE MENTOR/COOPERATING TEACHER, THE UNIVERSITY SUPERVISOR, AND THE INTERN/STUDENT TEACHER

The professional, collaborative training team consists of the mentor/cooperating teacher, the university supervisor, and the intern/student teacher. Each member of the team has a unique role that contributes to the professional growth and development of the intern/student teacher. *However, the roles are interdependent.* The success of the internship/student teaching experience hinges on the quality of the social and professional relationships developed within this triad. Continuous open, honest, three-way communication is critical for the professional triad to be effective.

ROLE OF THE MENTOR/COOPERATING TEACHER

- **Acknowledge the intern/student teacher as a** professional colleague **to students, faculty, and parents. Allow them to become part of the professional staff.**
- **Familiarize the intern/student teacher with the classroom, school, and community environments.**
- **Orient the student to the school curriculum.**
- ***Clarify at the beginning of the experience the specific roles and responsibilities of the intern/student teacher.* This will avoid potential problems.**
- **Model effective classroom instruction.**
- **Assist the intern/student teacher in planning instruction.**
- **Be willing to share resources.**
- **Provide opportunities for the intern/student teacher to observe you and other colleagues in a variety of disciplines and grade levels.**
- ***Serve as a coach, an encourager, and a nurturer.***
- **Observe the intern/student teacher teach and** provide both oral and written feedback **on their planning and preparation, classroom environment and management, instructional delivery, and assessment skills. Offer feedback in a positive and constructive manner.**
- **Invite the intern/student to *engage in reflective self-evaluation.*** Ask questions **that encourage the intern/student teacher to describe, evaluate, and refine all aspects of his/her teaching.**
- Complete one, formal written observation a week, using a university observation protocol.
- ***Verify the intern/student teacher's weekly hours and sign the weekly time sheets.***
- **Read the Intern/Student Teacher Handbook to become**

ROLE OF THE UNIVERSITY SUPERVISOR

The university supervisor is a member of the Pitt faculty who serves as the vital link between the university and the cooperating schools. Some supervisors are graduate students pursuing doctoral degrees in education. These individuals are generally certified teachers who work under the guidance of our full-time faculty. Most of them have also completed advanced graduate studies in teaching, teacher education, and staff development. Other supervisors are former teachers and/or administrators. All supervisors participate in regular clinical supervision training programs. Several members of our supervisory staff have previously served as mentor/cooperating teachers.

The university supervisor works closely with *BOTH* the intern/student teacher and the mentor/cooperating teacher.

Guidelines for Supervisors

- Interpret University policies, procedures, and requirements to all personnel involved in the internship/student teaching experience.
- Know the standards (criteria) to be used in assessing the intern/student teacher's performance.
- Observe the intern/student teacher's teaching seven times a semester.
- Evaluate on an on-going basis the intern/student teacher's performance in the classroom and on-site according to the domains of planning and preparation, classroom environment, instructional delivery, and professionalism.
- In Elementary Education, the university supervisor must observe the intern/student teacher teach lessons in Reading/Language Arts, Math, Science, and Social Studies.

ROLES AND RESPONSIBILITIES OF THE INTERN/STUDENT TEACHER

The intern/student teacher has many personal, professional, and academic obligations throughout this practicum experience. At the university, we place a strong emphasis on *professionalism*. We stress that they are graduate students in a professional program and, therefore, are expected to think and to conduct themselves as professionals at all times. If conflicts or problems arise, the intern/student teacher should first discuss these matters with his/her mentor/cooperating teacher and his/her university supervisor in a confidential manner.

ROLES AND RESPONSIBILITIES OF THE INTERN/STUDENT TEACHER

Most of these are listed below

- Become familiar with and follow the calendar of the cooperating school. This pertains to orientation days, in-service days, conference days, workshops, and holidays.
- *Follow the daily time schedule established by the district for the intern/student teacher*.
- **Be punctual! Consistent tardiness without sufficient cause is inexcusable**.
- **Dress in an appropriate professional manner**.
- Maintain regular attendance. The hours an intern is assigned to a cooperating school varies, but the minimum is 20 hours a week for the entire year. Student teachers are at their cooperating school all day for 14 weeks.
- *Report every absence and its reasons to the mentor/cooperating teacher through the school office* **as early as possible**. See handbook for excused absences.
- *Clear every absence with the university supervisor, as well as the mentor/cooperating teacher. Student teachers who miss more than five days will have to make up these days by extending their student teaching.*
- Give **ample prior notice** to the building principal, if a planned absence has been approved by the university supervisor and the mentor/cooperating teacher.
- Establish positive working relationships with all personnel in the cooperating school, with the university supervisor, and with university faculty.
- *Perform the same teaching and non-teaching duties as the mentor/cooperating teacher*, including participation in faculty meetings, parent-teacher conferences, staff development programs, extracurricular

familiar with guidelines, policies, and procedures.

- Complete the required midterm and final university evaluations and submit them to the university supervisor or the Office of Teacher Education**.**
- **Work closely with the university supervisor and the district site coordinator.** *Confer regularly with the intern/student teacher and the university supervisor concerning the intern/student teacher's progress.*
- ***If conflicts or problems arise, discuss them confidentially with the intern/student teacher and the university supervisor*.**
- **Participate in special university or school-based training sessions for mentors.**
- ***If you support the intern's entry into the profession, write a letter of recommendation for his/her university placement file.***

Finally, a mentor/cooperating teacher must remember that becoming a teacher is a gradual, developmental process **and that** your role is to guide the novice teacher through this first experience.

- Collect data on the intern/student teacher's performance using a variety of data collection instruments.
- **Videotape** the intern/student teacher teaching and *use the tape to allow the novice teacher to engage in in-depth reflective analysis of his/her teaching*.
- ***Confer with the intern/student teacher following each observation and share data with the intern/student teacher and the mentor/cooperating teacher.***
- Ask questions to encourage the intern/student teacher to become reflective about his/her teaching.
- ***Plan with the intern/student teacher and mentor/cooperating teacher specific areas that will receive attention in subsequent observations.***
- **Keep the Coordinator of Supervision, the Coordinator of Field Placements, and specialty area program faculty informed of the intern/student teacher's progress.**

functions, etc.

- *Organize the planning and implementation of instruction*. Both unit plans and lesson plans must be prepared and submitted to the mentor/cooperating teacher prior to implementation. This allows the mentor/cooperating teacher to offer suggestions and/or give approval to the intern/student teacher's plans.
- **Interns and student teachers must write a complete lesson plan for every lesson they teach. Block plans are NOT permitted.**
- **Interns/student teachers are responsible for submitting lesson plans to the mentor/cooperating teacher and the university supervisor by a mutually agreed upon deadline prior to each teaching assignment. *Copies of all lesson and unit plans should be retained by the intern/student teacher.***
- **Accept constructive feedback.** Use the supportive and corrective feedback given by the mentor/cooperating teacher and the university supervisor to become a ***reflective practitioner.***
- *Complete the Formal Reflection sheet or Formal Conference Feedback Form at the close of each conference*. Have the university supervisor or the mentor/cooperating teacher initial the form. Staple the reflection behind the formal, written observation.
- Furnish the university supervisor with a complete classroom schedule, including time. In addition, providing a map of the school and travel directions to the school would be helpful.
- **Complete the weekly, cumulative time sheet for each week of the internship/student teaching experience. After your mentor/cooperating teacher has signed the form, file the weekly time sheet in your folder. THIS IS A LEGAL DOCUMENT.**
- Complete all assignments made by the mentor/cooperating teacher and the university supervisor, in addition to all university course-related assignments.
- **FOR INTERNS ONLY:** Prepare a professional portfolio that highlights reflective thinking and multiple modes of instruction which includes evidence for the successful completion of the four domains of the **[state]** assessment.
- **Read the Intern/Student Teacher Handbook and familiarize yourself with all guidelines, policies, and procedures for the practicum experience.**

Appendix D

GENERAL INTERVIEW PROTOCOLS

General Interview #1 Protocol

Notes to interviewer:

- After asking the first question, let the teacher talk as much as possible. Use neutral prompts like "Hmm," "Oh," or non-verbal cues to encourage the teacher to continue talking.
- When the teacher is responding, write down key words or phrases. If you need to probe an idea to learn more about it, use the exact wording that the teacher used as often as possible.
- If the teacher covers elements of questions earlier in the interview, return to them by saying something like, "I know you talked about this earlier, but is there anything more you'd like to say about…"
- ***Admit your ignorance.*** If you don't understand what the teacher is talking about, avoid any verbal or non-verbal cues that might convey an understanding. Instead, use one of the general prompts listed to elicit more information.
- To begin the interview set up and turn on the audio recorder. Note the information below.

  - Interviewer: ________________________
  - Date: _____________________________
  - Class/Period: _______________________
  - Participant: (use pseudonym)
  - School: (use pseudonym)
  - Recorder: ______
  - Files: __________

This is (name of interviewer) interviewing (name of pre-service teacher) on (date). This is general interview #1.

Thank you for participating in the study.

This interview has two parts. The first part focuses on learning about you and your experiences thus far in your internship. The second part will focus on the upcoming series of lessons that I will be videotaping.

Part 1: Gathering Contextual Information

1. I'd like to talk about your internship.
    a. Tell me about (name of school).

    b. What are the students like?

    c. What classes do you teach?
        i. How long have you been teaching each of the classes?

    d. As you know, I'll be videotaping one particular class. Tell me more about (the focus class).
        i. Describe the students
        ii. Describe the type of class (honors, academic, etc)
        iii. How does this class compare to other classes you teach?
        iv. Is there anything else you'd like to say about this class?

    e. What is your typical day like?

2. Could you talk about your relationship with your mentor?
    a. Do you plan lessons together?
        i. Why/why not?
        ii. How, if at all, has this changed from the beginning of the year?
    b. What does your mentor expect from you as an intern?
        i. Have the expectations changed from the beginning of the year?
            1. in what ways?
            2. what prompted the changes?
    c. Is there anything else you'd like to say about your mentor?

3. How would you describe the philosophy of the mathematics department in your school?
    a. How is it similar to or different from what happens in your classroom when your mentor is teaching?
    b. How is it similar to or different from what happens in your classroom when you are teaching?
    c. How is it similar to or different from what you are learning in your coursework at Pitt?

    d. Is there anything else you'd like to say about the math department at your school?

4. What interactions do you have with other math teachers
    a. in your school?
    b. At the high school?

5. How are decisions made about what gets taught?

6. Is there anything else you'd like to say about your internship?

General prompts for elaboration on ideas that the teacher brings up:

Would you say more about [*use teacher's own words here*]?

Would you say more about what you mean by [*use teacher's own words here*]?

Would you give me an example [of that/what you mean by *teacher's own words*]?

If the teacher uses a word or phrase that you're not familiar with:
I'm sorry, I'm not familiar with what __________________ is. Would you tell me more about it?

Part 2: Gathering Instructional Information

We're going to move onto the second part of the interview. I'd like to talk more now about the upcoming lessons in the (period and name of class) that I'll be observing.

1. Would you please give me a sense of what's going to happen in the set of lessons you will be teaching over the next few days?

2. What is your mathematical goal for this series of lessons?

3. What sorts of problems, activities, or exercises will the students be working on?

   a. Where did they come from?

   b. If modified: Can you describe the modifications you made and your reasons for making them?

4. How did you decide to use those problems, activities, or exercises?
   a. What influenced your decision?
   b. Are these lessons "typical" of your usual lessons?
      i. (if yes) In what ways?
      ii. (if no) How are they different? Why are they different?

5. What do you see as your role during the upcoming lessons?
   a. Is it the same for each lesson?
      i. (if yes) In what ways?
      ii. (if no) How is it different? Why is it different?
   b. Is this your typical role in the classroom?
      i. (if yes) In what ways?
      ii. (if no) How is it different? Why is it different?

6. What do you see as the students' role during the upcoming lessons?
   a. Is it the same for each lesson?
      i. (if yes) In what ways?
      ii. (if no) How is it different? Why is it different?
   b. Is this the students' typical role in the classroom?
      i. (if yes) In what ways?
      ii. (if no) How is it different? Why is it different?

7. Is there anything else you want to tell me about the lessons I'll be observing that you haven't had a chance to talk about yet?
   If the teacher offers more information, follow up with:
   Anything else you want to say about the lessons?
   Anything else?

General prompts for elaboration on ideas that the teacher brings up:

Would you say more about [*use teacher's own words here*]?

Would you say more about what you mean by [*use teacher's own words here*]?

Would you give me an example [of that/what you mean by *teacher's own words*]?

If the teacher uses a word or phrase that you're not familiar with:
I'm sorry, I'm not familiar with what _________________ is. Would you tell me more about it?

General Interview #2 Protocol

Notes to interviewer:

- After asking the first question, let the teacher talk as much as possible. Use neutral prompts like “Hmm,” “Oh,” or non-verbal cues to encourage the teacher to continue talking.
- When the teacher is responding, write down key words or phrases. If you need to probe an idea to learn more about it, use the exact wording that the teacher used as often as possible.
- If the teacher covers elements of questions earlier in the interview, return to them by saying something like, “I know you talked about this earlier, but is there anything more you’d like to say about…”
- ***Admit your ignorance.*** If you don’t understand what the teacher is talking about, avoid any verbal or non-verbal cues that might convey an understanding. Instead, use one of the general prompts listed to elicit more information.
- To begin the interview set up and turn on the audio recorder. Note the information below.

- Interviewer: ________________________
- Date: _____________________________
- Class/Period: _______________________
- Participant: (use pseudonym)
- School: (use pseudonym)
- Recorder: ______
- Files: __________

This is (name of interviewer) interviewing (name of pre-service teacher) on (date). This is general interview #2.

Thank you for participating in the interview today. I'd like to talk about the 5 lessons I recorded during your (period, name of focus class) from (dates).

1. How do you think this set of lessons went?

    a. What aspects of the lesson went exactly as you thought they would?

    b. Are there any aspects of the lessons that surprised you?
    (*use* anything other *if some have already been identified)*

2. In the interview prior to the beginning of this set of lessons, you indicated that your mathematical goal for this series of lessons was (*repeat exactly what the teacher said in response to general interview #1, part 2, question 2*). Did this set of lessons help you meet that goal?

For question 3, use the instructional design decisions that the researcher identified from the classroom observations. (should be multiple decisions(3-5) for each teacher)

3. So I noticed that students did __________________. Why did you decide to have students do this during this set of lessons?
   Did it accomplish that goal?
   How do you know?
   Examples:

   So I noticed that students used algebra tiles in the activity on Wednesday. Why did you decide to have students use them during this set of lessons? Did it accomplish that goal? How do you know?

   So I noticed that when students had difficulty with the question you asked on Friday, you had them turn and talk to each other. Why did you decide to have them do that at that moment in the lesson? Did it accomplish that goal? How do you know?

   So I noticed that when you gave groups a task to work on Monday, you asked them to think and work individually on the task for a few minutes before talking with their group. Why did you decide to have students do this for that activity? Did it accomplish that goal? How do you know?

   So I noticed that when you deviated from your lesson plan on Monday when you _____. Why did you decide to do ______ instead of what was in your lesson plan? Did it accomplish that goal? How do you know? Were you satisfied with the result of the change?

For question 4, use the video clip(s) that the researcher identified from the classroom observations.

4. For this next question, I'd like for us to take a look at a short piece of video from your class and give you a chance to share your reflections on it.
   (Show video clip) (*Pause after showing the clip and allow the teacher to reflect spontaneously. When he or she is done speaking, probe as needed.)*

5. What was your role during the lessons?
   a. Was it the same for each lesson?
      i. (if yes) In what ways?
      ii. (if no) How is it different? Why is it different?

   b. During the initial interview, you stated that you saw your role as (*repeat exactly what the teacher said in response to general interview #1, part 2, question 6)*. Looking back over the lessons, how does your actual role compare to what you envisioned your role to be?

6. What was the students' role during the lessons?
   a. Was it the same for each lesson?
      i. (if yes) In what ways?
      ii. (if no) How is it different? Why is it different?

   b. During the initial interview, you stated that you saw the students' role as (*repeat exactly what the teacher said in response to general interview #1, part 2, question 7)*. Looking back over the lessons, how does the students' actual role during the lessons compare to what you envisioned the students' role to be?

7. Is there anything else you want to tell me about the lessons that you haven't had a chance to talk about yet?
   If the teacher offers more information, follow up with:
   Anything else you want to say about the lessons?
   Anything else?

8. When you think about planning to teach these lessons for next year to meet (*restate the teacher's math goal)*, what will you do? Why?

General prompts for elaboration on ideas that the teacher brings up:

Would you say more about [*use teacher's own words here*]?

Would you say more about what you mean by [*use teacher's own words here*]?

Would you give me an example [of that/what you mean by *teacher's own words*]?

If the teacher uses a word or phrase that you're not familiar with:
I'm sorry, I'm not familiar with what ________________ is. Would you tell me more about it?

Appendix E

LESSON CENTERED INTERVIEW PROTOCOLS

Pre- Lesson Interview

- Interviewer: ________________________
- Date: _____________________________
- Class/Period: _______________________
- Participant: (use pseudonym)
- School: (use pseudonym)
- Recorder: ______
- Files: __________

To begin the interview:
Complete information above.
Set up and turn on the audio recorder.
Begin with the opening question.

Pre-Lesson Interview Question

Please tell us what you're going to be doing in today's lesson and what you hope students will learn.

Reminders for the Observer

- Do **not** try to take field notes while recording. Focus on getting quality video and audio. If there are specific impressions you wish to write down, do so after class has finished.
- If displays are created of student work, make every effort to capture them on tape. If possible, take footage of them after class is over if they are still hanging publicly. (This can be done by shooting more video, or by using the still photo feature on the camera.)
- Try to transcribe all interviews when you return to the office later that day/evening.

Post-Lesson Interview

- Interviewer: ________________________
- Date: _____________________________
- Class/Period: _______________________
- Participant: (use pseudonym)
- School: (use pseudonym)
- Recorder: ______
- Files: __________

To begin the interview:
Complete information above.
Set up and turn on the audio recorder.
Begin with the opening question.

Post-Lesson Interview Questions

1. Thinking back on the lesson you just completed, how do you think it went?

2. In the interview prior to the beginning of this lesson, you indicated that your mathematical goal for this lesson was (*repeat exactly what the teacher said in response to pre-interview question 1*). Did this lesson help you meet that goal?

   a. (if yes) How?
   b. (if no)- Why not?

Reminders for the Observer

- Do **not** try to take field notes while recording. Focus on getting quality video and audio. If there are specific impressions you wish to write down, do so after class has finished.
- If displays are created of student work, make every effort to capture them on tape. If possible, take footage of them after class is over if they are still hanging publicly. (This can be done by shooting more video, or by using the still photo feature on the camera.)
- Try to transcribe all interviews when you return to the office later that day/evening.

Appendix F

CONTEXTUAL INTERVIEW PROTOCOLS

Contextual Interview Protocol

Notes to interviewer:

- After asking the first question, let the teacher talk as much as possible. Use neutral prompts like "Hmm," "Oh," or non-verbal cues to encourage the teacher to continue talking.
- When the teacher is responding, write down key words or phrases. If you need to probe an idea to learn more about it, use the exact wording that the teacher used as often as possible.
- If the teacher covers elements of questions earlier in the interview, return to them by saying something like, "I know you talked about this earlier, but is there anything more you'd like to say about…"
- ***Admit your ignorance.*** If you don't understand what the teacher is talking about, avoid any verbal or non-verbal cues that might convey an understanding. Instead, use one of the general prompts listed to elicit more information.
- To begin the interview set up and turn on the audio recorder. Note the information below.

- o Interviewer: ________________________
- o Date: _____________________________
- o Class/Period: _______________________
- o Participant: (use pseudonym)
- o School: (use pseudonym)
- o Recorder: ______
- o Files: __________

This is (name of interviewer) interviewing (name of interviewee) on (date). This is a contextual interview.

Thank you for participating in the interview today. The purpose of the interview is for me to gain insight into how you view certain aspects of mathematics education environment at (name of school).

Gathering Contextual Information

7. I'd like to talk now about the school..
    a. Tell me about (name of school).

    b. What are the students like?

    c. What classes do you teach?
        i. How long have you been teaching each of the classes?

8. I'd like to talk more now about (name of pre-service teacher).What is the typical day like for (name of pre-service teacher)?

9. Could you talk about your relationship with (name of pre-service teacher)?
    a. Do you plan lessons together?
        i. Why/why not?
        ii. How, if at all, has this changed from the beginning of the year?
    b. What do you expect from (name of pre-service teacher) as your intern?
        i. Have the expectations changed from the beginning of the year?
            1. in what ways?
            2. what prompted the changes?
    c. Is there anything else you'd like to say about your intern?

10. How would you describe the philosophy of the mathematics department in your school?
    a. How is it similar to or different from what happens in your classroom when you are teaching?
    b. How is it similar to or different from what happens in your classroom when (name of pre-service teacher) is teaching?
    c. Is there anything else you'd like to say about the math department at your school?

11. What interactions do you have with other math teachers
    a. in your school?
    b. At the high school?

12. How are decisions made about what gets taught?

13. Is there anything else you'd like to say about the environment at (name of school)?

General prompts for elaboration on ideas that the teacher brings up:

Would you say more about [*use teacher's own words here*]?

Would you say more about what you mean by [*use teacher's own words here*]?

Would you give me an example [of that/what you mean by *teacher's own words*]?

If the teacher uses a word or phrase that you're not familiar with:
I'm sorry, I'm not familiar with what ________________ is. Would you tell me more about it?

Appendix G

ACADEMIC RIGOR RUBRIC OF THE INSTRUCTIONAL QUALITY ASSESSMENT (IQA)

Academic Rigor

RUBRIC 1a: Potential of the Task (time one- in curricular materials) [15]

Did the task (in curricular materials) [16] have potential to engage students in rigorous thinking about challenging content?

4	**The task has the potential to engage students in exploring and understanding the nature of mathematical concepts, procedures, and/or relationships, such as:** • Doing mathematics: using complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly suggested by the task, task instructions, or a worked-out example); OR • Procedures with connections: applying a broad general procedure that remains closely connected to mathematical concepts. The task must explicitly prompt for evidence of students′ reasoning and understanding. For example, the task **MAY** require students to: • solve a genuine, challenging problem for which students' reasoning is evident in their work on the task; • develop an explanation for why formulas or procedures work; • identify patterns and form generalizations based on these patterns; • make conjectures and support conclusions with mathematical evidence; • make explicit connections between representations, strategies, or mathematical concepts and procedures. • follow a prescribed procedure in order to explain/illustrate a mathematical concept, process, or relationship.
3	**The task has the potential to engage students in complex thinking or in creating meaning for mathematical concepts, procedures, and/or relationships. However, the task does not warrant a "4" because:** • the task does not explicitly prompt for evidence of students' reasoning and understanding. • students may be asked to engage in doing mathematics or procedures with connections, but the underlying mathematics in the task is not appropriate for the specific group of students (i.e., too easy <u>or</u> too hard to promote engagement with high-level cognitive demands); • students may need to identify patterns but are not pressed for generalizations; • students may be asked to use multiple strategies or representations but the task does not explicitly prompt students to develop connections between them; • students may be asked to make conjectures but are not asked to provide mathematical evidence or explanations to support conclusions
2	The potential of the task is limited to engaging students in using a procedure that is either specifically called for or its use is evident based on prior instruction, experience, or placement of the task. **There is little ambiguity about what needs to be done and how to do it.** The task does not require students to make connections to the concepts or meaning underlying the procedure being used. **Focus of the task appears to be on producing correct answers rather than developing mathematical understanding (e.g., applying a specific problem solving strategy, practicing a computational algorithm).** **OR** The task does not require student to engage in cognitively challenging work; the task is easy to solve.
1	**The potential of the task is limited to engaging students in memorizing or reproducing facts, rules, formulae, or definitions. The task does not require students to make connections to the concepts or meaning that underlie the facts, rules, formulae, or definitions being memorized or reproduced.** OR **The task requires no mathematical activity.**
0	Students did not engage in a task.

[15] Adapted- added titles here for clarification
[16] Adapted- added titles here for clarification

Academic Rigor

RUBRIC 1b: Potential of the Task (time two- in lesson plan) [17]

Did the task (as planed) [18] have potential to engage students in rigorous thinking about challenging content?

4	**The task has the potential to engage students in exploring and understanding the nature of mathematical concepts, procedures, and/or relationships, such as:** • Doing mathematics: using complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly suggested by the task, task instructions, or a worked-out example); OR • Procedures with connections: applying a broad general procedure that remains closely connected to mathematical concepts. The task must explicitly prompt for evidence of students′ reasoning and understanding. For example, the task **MAY** require students to: • solve a genuine, challenging problem for which students' reasoning is evident in their work on the task; • develop an explanation for why formulas or procedures work; • identify patterns and form generalizations based on these patterns; • make conjectures and support conclusions with mathematical evidence; • make explicit connections between representations, strategies, or mathematical concepts and procedures. • follow a prescribed procedure in order to explain/illustrate a mathematical concept, process, or relationship.
3	**The task has the potential to engage students in complex thinking or in creating meaning for mathematical concepts, procedures, and/or relationships. However, the task does not warrant a "4" because:** • the task does not explicitly prompt for evidence of students' reasoning and understanding. • students may be asked to engage in doing mathematics or procedures with connections, but the underlying mathematics in the task is not appropriate for the specific group of students (i.e., too easy <u>or</u> too hard to promote engagement with high-level cognitive demands); • students may need to identify patterns but are not pressed for generalizations; • students may be asked to use multiple strategies or representations but the task does not explicitly prompt students to develop connections between them; • students may be asked to make conjectures but are not asked to provide mathematical evidence or explanations to support conclusions
2	The potential of the task is limited to engaging students in using a procedure that is either specifically called for or its use is evident based on prior instruction, experience, or placement of the task. **There is little ambiguity about what needs to be done and how to do it.** The task does not require students to make connections to the concepts or meaning underlying the procedure being used. **Focus of the task appears to be on producing correct answers rather than developing mathematical understanding (e.g., applying a specific problem solving strategy, practicing a computational algorithm).** **OR** The task does not require student to engage in cognitively challenging work; the task is easy to solve.
1	**The potential of the task is limited to engaging students in memorizing or reproducing facts, rules, formulae, or definitions. The task does not require students to make connections to the concepts or meaning that underlie the facts, rules, formulae, or definitions being memorized or reproduced.** OR **The task requires no mathematical activity.**
0	Students did not engage in a task.

[17] Adapted- added titles here for clarification
[18] Adapted- added titles here for clarification

RUBRIC 2a: Implementation of the Task (time three- in set-up) [19]

At what level did the teacher guide students to engage with the task in implementation?

4	**Students *were provided (through the set-up) with the opportunity to* explore and understand the nature of mathematical concepts, procedures, and/or relationships, such as:** • Doing mathematics: using complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly suggested by the task, task instructions, or a worked-out example); OR • Procedures with connections: applying a broad general procedure that remains closely connected to mathematical concepts. There is explicit evidence of students′ reasoning and understanding[20]. For example, students may have *been provided with the opportunity to*: • solve a genuine, challenging problem for which students' reasoning *will be* evident in their work on the task; • develop an explanation for why formulas or procedures work; • identify patterns and form generalizations based on these patterns; • make conjectures and support conclusions with mathematical evidence; • make explicit connections between representations, strategies, or mathematical concepts and procedures. • follow a prescribed procedure in order to explain/illustrate a mathematical concept, process, or relationship.
3	**Students *were provided (through the set-up) with the opportunity to* engage in complex thinking or in creating meaning for mathematical concepts, procedures, and/or relationships. However, the implementation does not warrant a "4" because:** • there is no *potential for* explicit evidence of students' reasoning and understanding. • students *may* engage in doing mathematics or procedures with connections, but the underlying mathematics in the task *will* not *be* appropriate for the specific group of students (i.e., too easy or too hard to sustain engagement with high-level cognitive demands); • students *have opportunity to* identify patterns but *do* not *have the opportunity to* make generalizations; • students *have opportunity to* use multiple strategies or representations but *do not explicitly have opportunity to make* connections between different strategies/representations were not evident; • students *have the opportunity to* make conjectures but *do not need to* provide mathematical evidence or explanations to support conclusions
2	Students *were provided (through the set-up) with the opportunity to* engage in using a procedure that was either specifically called for or its use was evident based on prior instruction, experience, or placement of the task. **There is little ambiguity about what needed to be done and how to do it.** Students do not *need to make* connections to the concepts or meaning underlying the procedure being used. **Focus of the *set-up* appears to be on producing correct answers rather than developing mathematical understanding (e.g., applying a specific problem solving strategy, practicing a computational algorithm).** OR **Student *were not given* cognitively challenging work; the task was easy to solve.**
1	**Students engage in memorizing or reproducing facts, rules, formulae, or definitions. Students do not make connections to the concepts or meaning that underlie the facts, rules, formulae, or definitions being memorized or reproduced.** **OR Students did not engage in mathematical activity.**
0	**The students did not engage in a task.**

[19] Adapted- added titles here for clarification

[20] Modified language to more closely align with the set-up portion of the lesson

RUBRIC 2b: Implementation of the Task (time four- implementation) [21]
At what level did the teacher guide students to engage with the task in implementation?

4	**Students engaged in exploring and understanding the nature of mathematical concepts, procedures, and/or relationships, such as:** • Doing mathematics: using complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly suggested by the task, task instructions, or a worked-out example); OR • Procedures with connections: applying a broad general procedure that remains closely connected to mathematical concepts. There is explicit evidence of students′ reasoning and understanding. For example, students may have: • solved a genuine, challenging problem for which students' reasoning is evident in their work on the task; • developed an explanation for why formulas or procedures work; • identified patterns and formed generalizations based on these patterns; • made conjectures and supported conclusions with mathematical evidence; • made explicit connections between representations, strategies, or mathematical concepts and procedures. • followed a prescribed procedure in order to explain/illustrate a mathematical concept, process, or relationship.
3	**Students engaged in complex thinking or in creating meaning for mathematical concepts, procedures, and/or relationships. However, the implementation does not warrant a "4" because:** • there is no explicit evidence of students' reasoning and understanding. • students engaged in doing mathematics or procedures with connections, but the underlying mathematics in the task was not appropriate for the specific group of students (i.e., too easy or too hard to sustain engagement with high-level cognitive demands); • students identified patterns but did not make generalizations; • students used multiple strategies or representations but connections between different strategies/representations were not explicitly evident; • students made conjectures but did not provide mathematical evidence or explanations to support conclusions
2	Students engaged in using a procedure that was either specifically called for or its use was evident based on prior instruction, experience, or placement of the task. **There was little ambiguity about what needed to be done and how to do it. S**tudents did not connections to the concepts or meaning underlying the procedure being used. **Focus of the implementation appears to be on producing correct answers rather than developing mathematical understanding (e.g., applying a specific problem solving strategy, practicing a computational algorithm).** OR **Student did not engage in cognitively challenging work; the task was easy to solve.**
1	**Students engage in memorizing or reproducing facts, rules, formulae, or definitions. Students do not make connections to the concepts or meaning that underlie the facts, rules, formulae, or definitions being memorized or reproduced.** **OR Students did not engage in mathematical activity.**
0	**The students did not engage in a task.**

[21] Adapted- added titles here for clarification

Appendix H

FACTORS ASSOCIATED WITH THE MAINTENANCE AND DECLINE OF COGNITIVE DEMAND

Factors associated with maintenance and decline of high-level demands.

Factors Associated with the Decline of High-Level Cognitive Demands	**Factors Associated with the Maintenance of High-level Cognitive Demands**
Routinizing problematic aspects of the task	Scaffolding of student thinking and reasoning
Shifting the emphasis from meaning, concepts, or understanding to the correctness or completeness of the answer	Providing a means by which students can monitor their own progress.
Providing insufficient time to wrestle with the demanding aspects of the task or so much time that students drift into off-task behavior	Modeling of high-level performance by teacher or capable students
Engaging in high-level cognitive activities is prevented due to classroom management problems	Pressing for justifications, explanations, and/or meaning through questioning, comments, and/or feedback
Selecting a task that is inappropriate for a given group of students	Selecting tasks that build on students' prior knowledge
Failing to hold students accountable for high-level products or processes	Drawing frequent conceptual connections
	Providing sufficient time to explore

Appendix I

PAIGE MORRIS' TASK FROM DAY 1

$y \geq x$ $\quad y = x$

<u>Steps to Graphing Linear Inequalities</u> (in slope-intercept form)

STEP1: Graph your boundary line. Decide whether to use a solid or dashed line.

a. Use a solid line when given $\geq$ or $\leq$

b. Use a dashed line when given $>$ or $<$

x y
(1, 4)
$y > x$

What is the boundary line of the inequality $\underline{y > x}$? ⇒ Dashed $4 > 1$

STEP 2: when in slope intercept form only

- shade above the line if $>$, $\geq$
- shade below the line if $<$, $\leq$

Problem 1: Tell whether the boundary line for each inequality is solid or dashed. Then tell whether you would shade the region above or below the line.

a). $y \leq 9x + 6$

b). $y > (2/3)x$ Above
Dashed

c). $y \geq -4x - 11$

d). $y < -1x + (1/4)$ Below
Dashed

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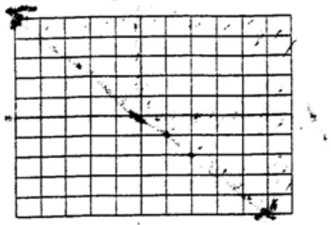
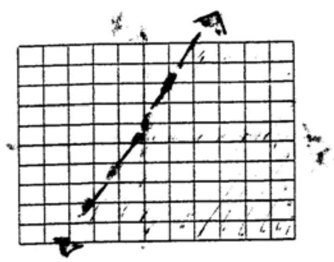
Example 1: **Graph and shade the solution to y ≥ -x**

a. The boundary line is ________________.

b. The line will be ______________.



Example 2: **Graph and shade the solution to y < 2x + 1**



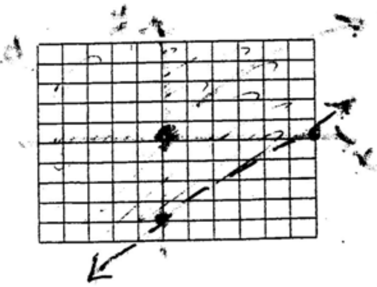
y = 2x+1
Dashed

How Do We Graph Inequalities in Standard Form?

Example 3: Graph and shade the solution to 8x - 12y < 48. Dashed

TEST
(0,0)
8·0-12·0<48
0<48

STEP 1:



STEP 2: ... not on the line and test it

... inequality true, shade where the pt is.

STEP 3: ... inequality false, shade opposite

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Appendix J

PAIGE MORRIS' TASK FROM DAY 2

8 - 7 Systems of Linear Inequalities

Objective(s):

Recall:
The ________________ of two lines indicate the solution of a system if you were graphing the equation of two lines.

The solution for a system of inequalities consists of:

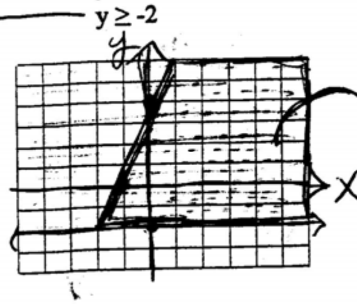
the overlapping shaded regions

Example 1: **Graph the following system of inequalities.**

$y \le 2x + 4$ → solid $y = 2x + 4$

solid ← $y \ge -2$

$y = -2$



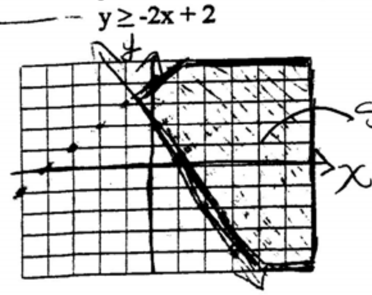
Solution Region

Example 2: **Graph the following system of inequalities.**

$y < x + 4$ → Dashed $y = x + 4$

solid ← $y \ge -2x + 2$

$y = -2x + 2$

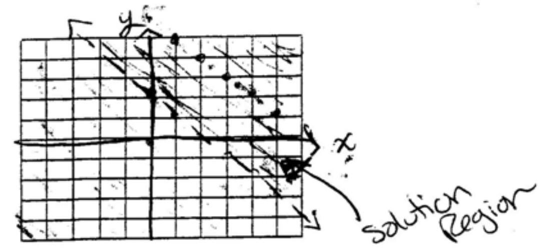


solution Region

Problem 1: Graph the following system of inequalities.

$y < -1x + 6$

Dashed ← $y > -1x + 2$

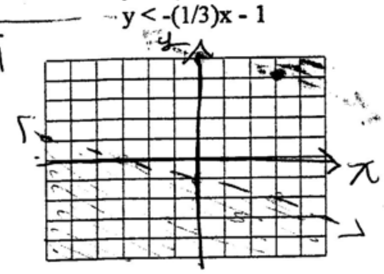


Problem 2: Graph the following system of inequalities.

$y > -(1/3)x + 5$ → Dashed $y = -1/3x + 5$

Dashed ← $y < -(1/3)x - 1$

$y = -1/3x - 1$



No solution ⇒ • lines are paralle

• slopes equal

Appendix K

PAIGE MORRIS' TASK FROM DAY 3

Name ______________________________ Date ______________

Practice 59

For use with Section 8-1

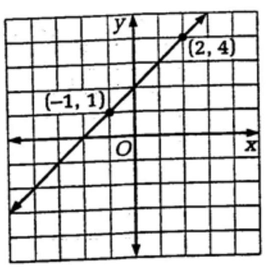
Without graphing, find the slope and the vertical intercept of the line modeled by each equation.

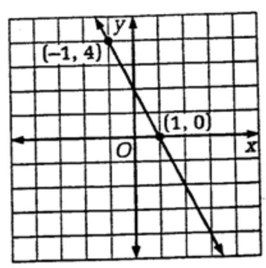
1. $y = 9x + 5$
2. $y = -8x + 7$
3. $y = 11 - 4.6x$
4. $y = x + 15$
5. $y = -2 + 12x$
6. $y = -17x$

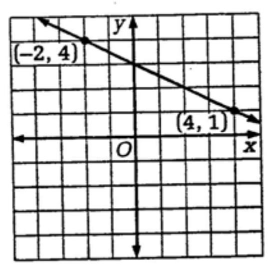
Graph each equation.

7. $y = x - 1$
8. $y = -x + 3$
9. $y = 0.5x - 3$
10. $y = -3x + 2$
11. $y = -0.2x + 4$
12. $y = 4 - \frac{1}{2}x$

For Exercises 13–15, find the slope and vertical intercept of each line. Write an equation of each line.

13.


14.


15.


Model each situation with an equation.

16. Jing walked toward his apartment at 3 mi/h from a point 5 mi from the apartment. (control variable: time; dependent variable: Jing's distance from home)
17. A garage charges $14 for an oil change plus $1.50 for each quart of new oil. (control variable: amount of new oil; dependent variable: cost of oil change)
18. The temperature of a laboratory sample of liquid oxygen is at –210°C, and it is rising at 7°C each minute. (control variable: time; dependent variable: temperature)
19. *Writing* How are linear functions and direct variations related? Explain how the graphs of the two types of functions are alike and how they are different.

Appendix L

PAIGE MORRIS' TASK FROM DAYS 4 AND 5

INTEROFFICE MEMORANDUM

TO: ALL STAFF WRITERS

FROM: ED I. TOR

SUBJECT: UPCOMING ISSUE

DATE: 12.20.04

CC: [redacted]

Your new assignment for this week's feature article in *Sports Illustrated* is to predict the future record for the Olympic women's 400 meter freestyle swimming event. In recent years, the records have been getting faster and faster. You are to write an article based on past Olympic results and make your prediction for the 2008 Olympics.

To write the article, you will need to assume different roles. You will both need to use your mathematical reasoning to analyze the past results and make your predictions. See your Integrated Math 1 book for assistance. As researchers, you will explore different resources to gather necessary data. Olympic history, past swimming results, swimming techniques, and advancements in athletic technology should all be examined. As reporters, you will use the information gathered to construct an article that discusses the predicted time. You should write the story according to the proper newspaper story format. See your Writer's Craft book and newspaper stories for models. As photographers, you will graphically design and organize the layout of the page. You may want to use Internet photographs, CorelDRAW, and Microsoft Word to aid in the construction of the data display on the page. The final role you will assume will be that of the editor. To perform this role, you will need to stylistically and grammatically edit the article. All components of the article should be considered in the editing process.

The deadline for this article is [redacted], so that we may include it in the next issue. Refer to the time line given to you to help you plan your time. You may want to utilize all of your available resources.

Good luck! ☺

Resources
Writer's Craft
Integrated Math 1
Almanac
CorelDRAW
Microsoft Office
www.infoplease.com
Encarta
TI-83 calculators

Tentative Timeline
03.30.06
Complete brainstorming activity

The purpose of the brainstorming activity is to gather ideas about the newspaper page.

- Gather Olympic times and other research

  HOMEWORK: RESEARCH

03.31.06 - 04.04.06

- Work on Project Problems

  The purpose of the project problems is to work through and analyze data to help you make predictions.

  HOMEWORK: FINISH PROJECT PROBLEMS

  PROJECT PROBLEMS MUST BE COMPLETED WHEN YOU ARRIVE IN CLASS TOMORROW

04.05.06

- Draft the article content and design

  HOMEWORK: HAVE A COMPLETED DRAFT READY FOR THE COMPUTER LAB TOMORROW

04.05.06 - 04.07.06

- Space available for those who are ready to word process the article in the computer lab

3 PM ON 04.17.06—DEADLINE
ALL ARTICLES MUST BE SUBMITTED BY 3 PM IN ORDER TO MEET THE NEXT ISSUE'S DEADLINE

BRAINSTORMING QUESTIONS

With your partner, please answer the following questions.

1. Think about how you will organize the data you will collect. Will you use a spreadsheet? What else could you use?

2. You should include some graphs in your article. You may want to review some of the data displays we discussed in Chapter 3. What were some of the data displays we learned about in Chapter 3?

Winning Times: Olympic 400m Freestyle Swimming 1960-2004		
	Men	*Women*
Year	*Time (seconds)*	*Time (seconds)*
1960	258.3 (AUS)	290.6 (USA)
1964	252.3 (USA)	283.3 (USA)
1968	249.0 (USA)	271.8 (USA)
1972	240.27 (USA)	259.44 (USA)
1976	231.93 (USA)	249.89 (E. GER)
1980	231.31 (USSR)	248.76 (E. GER)
1984	231.23 (USA)	247.10 (USA)
1988	226.95 (E. GER)	243.85 (USA)
1992	225.0 (UT)	247.18 (GER)
1996	227.97 (N ZEA)	247.25 (IRE)
2000	220.59 (AUS)	245.80 (USA)
2004	223.10 (AUS)	245.34 (FRA)

3. What information can you learn about the 400m freestyle times just by looking at the matrix?

4. Suppose you wanted to predict the winning time for the men's 400m freestyle in the year 2012. What information do you need to know? Could a scatter plot and a line of best fit help you?

5. What factors do you think have caused Olympic records to improve?

6. Records for Olympic sports have been improving ever since modern-day Olympics were first held in 1896. Do you think the records can continue to improve forever? Why or why not?

7. Describe some of the advantages that modern day athletes have over earlier Olympic athletes.

8. Do you think events occurring now help you to predict future events? Explain.

9. What types of predictions have you made in your life? What information have you used to help make a prediction?

PROJECT PROBLEMS

With your partner, you will complete the following problems. They will help guide you as you write the newspaper article.

1. Use the data chart for the Olympic 400m freestyle swimming event.
   a. Find the rate of increase for the women between the years 1972 and 1976.

   b. Find the rate of increase for the men between the years 1972 and 1976.

   c. Did the men or the women show more improvement in their times between 1972 and 1976? Describe two different ways you can justify your choice.

   d. *True or False?* The rates of change in the men's and women's times have been negative for the Olympic data. Describe how this is shown in a graph of data. How is it shown in the table?

2. Using a TI-83 calculator, create a scatter plot of the data. Use *the years after 1960* as the control variable and the *women's 400m freestyle swimming times* as the dependent variable. Use the graphing calculator to find the equation of the line of best fit. See your unit 4 notebook or Mrs. Knox if you have questions on how to do this.
   Sketch of the scatter plot:

   Line of best fit:____

3. Using a TI-83 calculator, create a scatter plot of the data. Use *the years after 1960* as the control variable and the *men's 400m freestyle swimming times* as the dependent variable. Use the graphing calculator to find the equation of the line of best fit. See your unit 4 notebook or Mrs. Knox if you have questions on how to do this.
Sketch of the scatter plot:

Line of best fit:____

4. The equations of the fitted lines for the graphs of some California high school record times are given. In the equations, x is the years since 1957 and y is the record time in seconds.

   Girls' 400m Individual Medley: $y = -1.95x + 335.05$

   Boys' 400m Individual Medley: $y = -1.86x + 299.1$

   a. Use a graph to estimate a solution of the system of equations.

   b. Use substitution to find a solution.

   c. What do the coordinates of the solution mean?

6

5. Using the equations for the lines of best fit that you found above, create and solve a system of equations to model when the men's and women's winning times will be equal.

COMPLETING THE PROJECT

Now you can analyze the trends in the Olympic swimming data. Make each of these predictions.

- ✓ In what year will the men's and women's winning times for the 400m freestyle event be equal?
- ✓ How will the men's and women's times compare in the years after they are equal?

Write your news article predicting the new record breaking time for the women's 400m freestyle swimming event. Use graphs to present some of the information in your article.

GRADING RUBRIC

	5	4	3	2	1
Project Problems	Brainstorming and Project Problems are fully completed. All questions are answered clearly and completely.	1-2 problems are incomplete or incorrect.	3-4 problems are incomplete or incorrect	5-6 problems are incomplete or incorrect.	More than 6 problems are incomplete or incorrect.
Content	You use the correct mathematical model to make a prediction and correctly analyze Olympic trends. You have found the correct time that the men's and women's times will be equal. You have the correct new record time. You support your prediction fully.	You have the correct models but have not correctly modeled the situation with a system and solution. You have analyzed the trends and made the correct prediction for the new record time. You support your prediction fully with the mathematics.	You have used mathematical models to make predictions and analyze the trends in Olympic data. Your predictions are slightly inaccurate, due to a computation or calculation error.	Your predictions are mathematics are inaccurate but you use them in the correct fashion, finding the solution to the system and predicting a new record.	Your predictions are completely inaccurate with no supporting mathematics.
Newspaper Story Form, Punctuation and Capitalization	You have used proper newspaper story form. You have a clear topic sentence, specific supporting details and a strong concluding sentence. You have used proper punctuation throughout your article. You have used proper capitalization through your article.	You have a topic sentence and a concluding sentence, but your supporting details are vague. You have made 1-2 errors in punctuation. You have made 1 error in capitalization in your article.	You are missing either a topic sentence or a concluding sentence, and your supporting details are vague. You have made 3-4 errors in punctuation. You have made 2 errors in capitalization in your article.	You have supporting details but do not include a topic or concluding sentence. You have made 5-6 errors in punctuation. You have made 3 errors in capitalization in your article.	You do not use proper newspaper story form. Your sentences are incomplete, and you have handed in essentially notes. You have more than 6 errors in punctuation. You have made more than 3 errors in capitalization in your article.

Project Problems __________ * 2 = ____________

Content __________ * 2 = ____________

Form __________ * 1 = ____________

Total _______ **out of 25**

9

Appendix M

EXAMPLE OF KEITH NICHOLS' LESSON PLAN

Day 1

Algebra: The Devil and Daniel Webster

Goal – Consider a real life problem that has an exponential context. Find an exponential formula that fits the situation.

Pass back Tests

Launch –

Ask – Can anyone think of a real life situation that could be expressed with exponents?
Ask –
Ask – Does anyone know what commission is?

Hand out worksheets:
Read story:
Have students write their impression of whether or not they would take the offer.
Make certain that students understand how the process works. The amount that they have left at the end of the day is the amount of their salary minus the commission. This difference is what gets doubled for the next day.

Explore – Students work to complete the worksheet in small groups.

.
Summary –
Ask – What kind of relationship does the commission and number of days have? (exponential)
Ask – What formula did you come up with to tell you the amount of commission based on the number of days?

Ask – What do you think the relationship between the number of days and the salary is?
Ask – Do you think it is exponential?

Ask – What would it be if we didn't have to worry about subtracting the commission? Refer to worksheet. Start with 1000. To get to the next day, you do "about" what to the 1000? (double it). Then to get the next one after that you do about what to 2000? (double it)
OK, but you're not really just doubling them. You have 1000 and you double it then subtract a little. Then you double 2000 and subtract a little more. Then you double 4000 and subtract a bit more than before.
Ask – What do you think this graph would look like? (it would start going up and then slope downward)
Ask – Does the graph for commission every slope downward? (no)
If commission is a bad thing for you and it is always increasing, and salary is a good thing and it only increases for a little while, does this sound like the kind of permanent job you would want?

Ask – What does it mean if the line representing salary crosses the y axis? (it means that you are making negative $)
Ask – Does this seem like a reasonable real life situation? Why not?

Demonstrate on Graphing Calculator how to find the exponential regression formula. Recall how to do this for linear regression. If all of the data points are actually generated by an equation this ExpReg will give you that equation.

Try it for Salary to see what you get. How accurate do you think this is? (look at r squared value)

Appendix N

KEITH NICHOLS' TASK FROM DAY 1

Name:________________________________

The Devil and Daniel Webster

The devil made a proposition to Daniel Webster. The devil proposed paying Daniel for services in the following way: On the first day, I will pay you $1000 early in the morning. At the end of the day, you must pay me a commision of $100. At the end of the day, we will both determine your next day's salary and my commision. I will double what you have at the end of the day, buy you must double the amount that you pay me. Will you work for me for a month?

1. After reading the salary proposal, decide if you would work if you were Daniel. Write down your answer.

   ____

2. Complete the following chart.

Number of Day	Salary for Daniel Webster	Commision
1	$1000	$100
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
...		
30		

3. On the basis of the table you completed, would you stand by your decision?

   ____________________ Explain why or why not. ____________________

   ____

   ____

4. If you would not work for a month, for how many days would you work?

   ____

5. From reading the problem, what type of curve would you expect your salary data to generate?

   ____

6. From reading the problem, what type of curve would you expect the commission data to generate?

   ____

7. Is the salary scheme realistic?____

Discussion and Extension

1. If you graphed your salary data, what type of graph would you expect to obtain?

   _________________________ Why? ___________________________________

   ____

2. In your own words, compare the graphs of the salary data and the commision data.

   ____

   ____

Appendix O

KEITH NICHOLS' TASK FROM DAY 3

Day 3

Name__________

Customer	Seed ($3.99)	Cuttlebone ($2.00)	Millet ($24)	G. Paper ($2.29)	Perches ($1.89)
Davis			X		
Brooks	X	X			
Casic	X		X		
Martino	X			X	X

Write an expression which represents the cost of Casic's order.

Write an expression which represents the cost of Davis', Brooks', and Martino's orders.

Martino buys 10 bags of birdseed, 4 packages of gravel paper, and 2 packages of perches. What is the total cost of his order?

A _________ is an expression that is a number, a variable, or a product of a number and one or more variables.

Give a few examples:

Is the expression c/x a monomial?

The ________ of a monomial is the sum of the exponents of its variables.

What is the degree of constant, like, 5 or 8?

This monomial, _____, has no degree.

Find the degree of each monomial:

1) $(2/3)x$ 2) $7x^2 y^3$ 3) -4

What is the degree of $9x^0$?

A ________________ is a monomial or the sum or difference of two or more monomials.

______________ of a polynomial means that the degrees of its monomial terms decrease from left to right.

The__________ of the polynomial in one variable is the same as the degree of the monomial with the highest exponent.

What is the degree of $3x^4 + 5x^2 - 7x + 1$?

Polynomial	Degree	Name Using Degree	Number of Terms	Name Using Number of Terms
$7x + 4$				
$3x^2 + 2x + 1$				
$4x^3$				
$9x^4 + 11x$				
5				

Example –
Write each polynomial in standard form. Then name each polynomial based on its degree and number of terms.

a) $5 - 2x$

b) $3x^4 - 4 + 2x^2 + 5x^4$

Example 3 – Adding Ploynomials
Method 1: Add vertically. Line up like terms. Then add the coefficients.

Simplify: $(4x^2 + 6x + 7) + (2x^2 - 9x + 1)$

Method 2: Add horizontally. Group like times. Then add the coefficients.

Simplify: $(3x^2 - 4x + 5) + (2x^2 - 8x + 1)$

Use any method:
Simplify the following:

a) $(12m^2 + 4) + (8m^2 + 5)$

b) $(t^2 - 6) + (3t^2 + 11)$

c) $(9w^3 + 8w^2) + (7w^3 + 4)$

d) $(2p^3 + 6p^2 + 10p) + (9p^3 + 11p^2 + 3p)$

Example 4 – Subtracting Polynomials

Simplify: $(2x^3 + 5x^2 - 3x) - (x^3 - 8x^2 + 11)$

Method 1: Subtract Vertically

Simplify: $(4x^3 + 7x^2 - 10x) - (19x^3 - 2x^2 + 21)$

Method 2: Subtract Horizontally

Examples:

a) $(v^3 + 6v^2 - v) - (9v^3 - 7v^2 + 3v)$

b) $(30d^3 - 29d^2 - 3d) - (2d^3 + d^2)$

c) $(4x^2 + 5x + 1) - (6x^2 + x + 1)$

Error Analysis: Mr. MacPherson's work is shown below. What mistake did he make?

$$\begin{aligned}(5x^2 - 3x + 1) - (2x^2 - 4x - 2) &= 5x^2 - 3x + 1 - 2x^2 - 4x - 2 \\ &= 5x^2 - 2x^2 - 3x - 4x + 1 - 2 \\ &= 3x^2 - 7x - 1\end{aligned}$$

Critical Thinking: Is it possible to write a binomial with a degree of zero? If yes, write one. If no, explain why not.

Appendix P

KEITH NICHOLS' TASK FROM DAYS 4 AND 5

Name_______________

Multiplying and Factoring

Multiplying a Monomial and a Binomial: Use algebra tiles to complete the multiplication and sketch your proof.

1. (-4x)(x + 1)

2. (2y)(-y+2)

3. (x-3)(-3x)

4. (-5x)(x+2)

Finding the Greatest Common Factor: Use algebra tiles and sketch your proof:

1. X^2+2x

2. -4X^2 – 4

3. X^2 – 2x

4. 5x + 5

Factoring out a Monomial: Factor and Sketch your proof.

1. 3X^2-3x

2. 2X^2+4X

3. -(3X^2) – 6x

4. 4X^2

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